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IDENTIFICATION OF HUMAN BEINGS BY THE SYSTEM OF ALPHONSE BERTILLON.*

(*Concluded.*)

BY
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DESCRIPTION OF REGISTER FILES.

It is necessary here with this rough sketch of the stacks in view to claim your close attention to a description of the method by which M. Bertillon classifies the records. This device of his is the real heart of the whole system. Anybody can construct a system of measurements which will differentiate living beings from each other, but to construct a means of so classifying them that one can go almost immediately to the case in which the previous record of an unrecognized but suspected recediviste or old offender will be found, requires the highest order of invention.

The function of the anthropometric service is to obtain from the prisoners brought to it a certain number of osseous measure-

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[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

ments, using the figures thus obtained as a basis to classify the photographs of individuals, after the manner of a classification of flora, etc., to enable one ultimately to find, in a collection

FIG. 11.

Age appt ——. Age déclaré —— Né en 18 ——

Taille 1m —— | Tête: long —— larg —— zygm — — | Pied g. —— Médius g. —— Auricre g. —— Coudée g. —— | Couleur de l'Iris: nre de cl. —— aur —— vér —— pariés —— | Cheveux —— Barbe —— Teint Pre —— Sre —— Main dr. —— Main g. ——

Taille —— Buste —— Enverg. —— Voûte —— Oreille dr. ——

(Point de vue 2/3 — Réduction 1/7)

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Pouce dr. Index dr. Médius dr. Annulaire dr. Auriculaire dr.

destined to contain several hundred thousand specimens, the portrait of an old offender who has concealed his identity under a false name and a disguise.

Suppose the collection to contain sixty thousand records. The first division is based on the longer diameter of the skull. In all cases the order is from small to great. Then the division containing records of these would be

short *heads*	↓	20,000
medium *heads*		20,000
long *heads*		20,000

Each of these three divisions of 20,000 is further divided into

narrow *heads*		6000+
medium *heads*	→	6000+
broad *heads*		6000+

Each of these three divisions of 6000 is further subdivided into

long *middle fingers*	↑	2000
medium *middle fingers*		2000
short *middle fingers*		2000

Each of these last divisions of 2000 is further subdivided into

short *left foot*		600+
medium *left foot*	→	600+
long *left foot*		600+

These again into

long *left forearm*	↑	200
medium *left forearm*		200
short *left forearm*		200

These further into

small *little finger*		60+
medium *little finger*	→	60+
long *little finger*		60+

These into

long *right ear*	↑	20
medium *right ear*		20
short *right ear*		20

These into heights

short		6+
medium	→	6+
tall		6+

and these six remaining from the 60,000 original cases are further differentiated by the color of the eyes. So that but a few minutes would elapse from the first glance into the head-length box till the agent had traced the individual whose record-slip was given to him down to the ear-division, and selected by the

eye-color determination which of the six slips if any correspond to that in his hand.

With six anthropometric characters (those of sex, height, age, eye-color have always been used) sixty thousand photograph-records of the préfecture of police are reduced to divisions of a dozen photographs which are easily scrutinized.

To maintain a classification of this character at a uniform number of cases it is necessary, in the first place, to pay attention to the presumed age to within twenty years, so that the persons born 1830–49, 1850–69, 1870–89, will fall together. In searching the files as described when the measure indicates a place near the dividing line, say between small and medium, one must search both divisions.

A table is given showing the numerical indication of the limits of each tripartite division up to and including the elimination by the forearm; the grouping being taken exactly from the order and disposition observed in the separate cupboards. Each of these sections in cupboard I, II, and III is employed by a different category of head-length: 1, small, 2, medium, 3, large. The vertical pieces which divide them into three parts separate the three divisions of head-breadth. Each of these parts is again redivided into three, corresponding to the three divisions of the middle finger.

Each of these small sections increasing from below upwards is again subdivided by vertical walls increasing from left to right for the foot; and each of these latter is again divided from below upwards for the forearm.

Each of the smallest divisions is contained in a small box called a cabriolet, like the similar boxes in desk files, which bears on its front end the following inscriptions:

I.—Head length IV.—Foot
II.—Head breadth III.—Middle finger
V.—Forearm.

The maximum and minimum values found by experience to apply to each of these five divisions in this section of the anthropometric files is affixed to it.

The photographic print added to the numerical record for each person is composed of two pictures juxtaposed; the one, a profile of the right side of the face, and the other a full view, both exactly one-seventh natural size.

On the back of the photographic card are data giving with the precision of anatomic description all the cicatrices, simple marks, or cuts, etc., which each individual possesses.

The measures, the photographs, and this description of special marks permit the determination of an individual after many years of interval to a very high degree of certainty.

To make it still clearer: you observe the sets of three stacks joined together but separated by vertical partitions. The picture only represents twelve horizontal shelves and three of the nine vertical subdivisions.

Imagine twenty-seven shelves divided by horizontal lines into three sets of nine shelves each; and three groups of stacks divided by vertical lines into three sets of triple stacks like the one you see in the picture. The upper nine shelves are devoted to small head lengths, the middle nine shelves contain medium head lengths; and the lower nine shelves large head lengths from left to right throughout the entire series of nine stacks.

The three highest vertical divisions on the left contain small head breadths; the middle three vertical divisions medium head breadths; and the three stacks on the right hand large head breadths.

These two capital divisions (in both senses) I and II head lengths and breadths sweep from the left-hand upper corner downward in increasing head lengths. Head breadths are also found on the uppermost shelf to the left and grow in size in lines to the right upwards from bottom to top and across from left to right of the entire system of twenty-seven horizontal and nine vertical divisions. The smallest head length will be found recorded on the upper row to the extreme left. It is 18.3 cm. on the upper nine shelves; 18.4 on the middle nine shelves, and 19 on the lower nine shelves.

These figures are used by M. Bertillon to cover freaks: –18.3 means from the smallest possible head length observed (theoretically just above 0) to 18.3 cm.; and 19–, from 19 cm. to the largest possible measure.

The smallest head breadth will also be found in the upper left-hand cabriolet. It is –15.2 throughout the left-hand three vertical divisions; 15.3–15.7 through the middle three vertical divisions; and 15.8– throughout the three right-hand vertical divisions.

Datum III or the length of the left middle finger divides horizontally each of the first-mentioned grand divisions into three parts containing three shelves each, but in each of these the increase of number is from below upward and not, as in the head length, from above downward.

Datum IV or the length of the left foot divides each of these last-mentioned groups of three shelves into three of a single shelf each, in this case also increasing numerically upward. Finally Datum V, the length of the left forearm, is classified in three cabriolets on each shelf, the numbers increasing from left to right.

Suppose a prisoner presents the slip containing the records of measurements just made by the measuring officers to the officer who presides over the records, and that this slip contains the data I—18.6, II—15.7, III—11.3, IV—25.7, V—45. The case is purposely chosen because it lies in the least definite part of all the data—the medium. Nevertheless the agent would promptly go to the middle nine shelves representing the medium head length, and passing to the right would halt at the section containing the middle vertical group of three stacks and the middle

horizontal group of nine shelves. He would do this because the head breadth of the left-hand group of three stacks is shorter than the datum and the right-hand group of three is longer.

Somewhere there among these twenty-seven shelves will be found the measure of the prisoner if one there is.

He would eliminate the top and bottom groups of three shelves each because on these the datum III or little middle finger length would be too small or too large. By datum IV the left foot length he would eliminate the upper and lower shelves of this middle group of three shelves and thus there would remain but three vertical divisions of the middle shelf of the middle section. Here datum V, the length of the fore-arm 45, would at once decide him to look into the middle cabriolet of the middle shelf and there he would find—if it had been taken—the measurements of his man together with his real name and civil station.

In anthropometric classification, the designation of the classes small, medium, large, it follows that the medium must be the narrowest division.

Suppose we begin a search by the element of height, the medium division will include only those with a height of 1.62 M. (5.41 ft.) to 1.67 M. (5.47 ft.), whereas the larger will include those from 1.68 M. (5.51 ft.) to the giant of 2 meters (6.56 ft.), and the small will include those with a height of 1.62 M. to the liliputian of 1. M. (3.3 ft.) and a few centimetres.

The division of the binomial curve shows that to realize this condition in a general way the limits of the category of medium must not vary above nor below the arithmetical mean more than an amount equal to 0.63 of the probable error or half the variation of half of the cases. It follows as a matter of course that the arithmetical mean of each measurement varies according to the division small, medium, or large, of the preceding measurement. It is thus that in parting from the elimination by the middle finger to that by the foot, the arithmetical mean of the foot of those endowed with a small middle finger will be notably different from the similar value observed in those with a large middle finger.

M. Bertillon has strictly forbidden his employés from informing the interested individual when he is identified. A few notes are taken and he is dismissed to the depot, but the facts are put into the possession of the magistrate who is to try him, and this will explain the frequent dramatic sensations produced when, after the prisoner arraigned before the magistrate, has answered that his name is Jean Bourdet, a carpenter, living in the Rue Mesnil, unmarried, and twenty-four years old, the genial justice replies: your name is Eugene Tridot; you were arrested for highway robbery and attempted assassination on June 17, 1902; you were also imprisoned for beating your wife almost to death; you were born in Lyons, are thirty-seven years old and have served three terms of imprisonment.

In more than 2300 recognitions thus transmitted to the trial magistrates not a single one has caused any confusion or embarrassment which a mistake would have been sure to occasion.

FINGER PRINTS.

For a long time after Francis Galton had made known the usefulness of finger prints for distinguishing individuals M. Bertillon took no notice of the method. Singularly enough Galton began his study in 1888 indirectly through the instigation

FIG. 12.

of the Bertillon system. He says (in the introduction of the edition of 1892), "My attention was first drawn to the ridges in 1888 when preparing a lecture on personal identification for the Royal Institution, which had for its principal object an account of the anthropometric method of Bertillon then newly introduced into the prison administration of France." Further on (p. 15) he makes this statement: "For aid in searching the

records of a criminal bureau its (the method of finger prints) proper rank is probably a secondary one; the primary being some form of the already established Bertillon anthropometric method. Whatever power the latter gives of searching registers that power would be multiplied many hundred fold by the inclusion of finger prints, because their peculiarities are entirely unconnected with personal characteristics." * * *

In this same book is an interesting examination of the merits of Bertillon's system (chap. X).

Galton found after classifying 500 Bertillonized cases by taking the measures of head length, head breadth, span, body height and middle finger, the results were not entirely satisfactory. Eighty-three possible cases out of 243 (3^5) or ⅓ of the total number possible were not represented at all in actual observation. Twenty-four sets fell under one head in one instance; in others 14, 11, and 10 did so. The case was different where instead of five, seven measures were taken. He believes that this number of datum points will enable one easily to separate and individualize 500 cases, and perhaps many more.

Galton's method of classifying finger prints is thus given (p. 71) in his book.

"It may be convenient when marking finger prints with letters for reference to use those that look alike both in a direct and in a reversed aspect, as they may be required to be read either way. The print is a reversed picture of a similar pattern on the digit that made it." * * *

There are twelve capital letters of the English alphabet which in block type are unaffected by being reversed; namely, A, H, I, M, O, T, U, V, W, X, Z. Some symbols, such as *, +, —, =, do the same; and H, O, I, X have the further peculiarity of appearing unaltered when upside down.

He divides the patterns of finger prints into three categories: arches, loops, and whorls.

When M. Bertillon comparatively recently finally decided to avail himself of these wonderful phenomena to strengthen his system, he made his own classification, rejecting Galton's. To this end the four vowels "e," "i," "o," "u" are used to indicate the four types into which the patterns of the finger prints are divided.

The type "e" was that pattern in which the lines forming the loops resting on the usual triangle of intersection near the middle of the impression extend from left to right downward; their closed ends being above and to the left, and the free ends descending to the right. To justify the designation there must be at least two such loops.

The type "i" is that pattern where at least two ridges indicated by black lines in the impression have their closed ends to

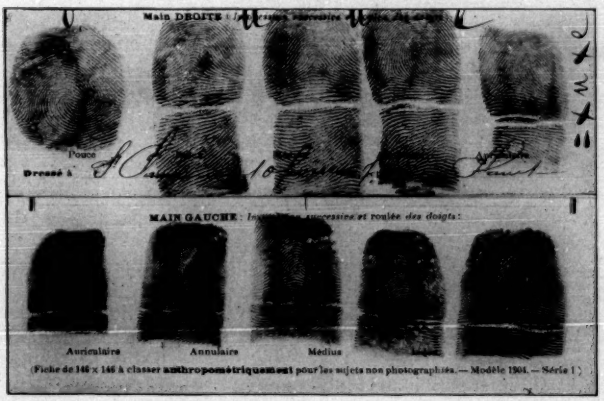
the right, above the triangular places of intersection, forming an oval, or spiral, the latter either concentric or as volute.

The type "o" is that where the digital lines appear to the number of at least 4 between the little triangular patterns marking the central point of each finger tip; and their form is oval, spiral, or volute.

The type "u" is that pattern in which the lines are superposed in the form of an arch, flat near the bottom and higher on top.

The prints are taken in the following manner: A plate of

FIG. 13.



Specimens of finger prints.

zinc or glass is covered uniformly with printer's ink rolled out to a thin film, the person whose finger prints are to be taken is placed to the left of the operator who takes the subject's right hand and keeps, successively, the thumb and the other digits extended by taking the extremity of each in turn between the thumb and index of his own right hand and holding the base of the finger with his left hand. The front of the third joint of each finger in turn is then rolled lightly on the plate covered with ink, and immediately afterwards the same action is repeated, the inked surface being rolled on the card which is to receive the impression.

It is only the cuticle of the phalanges at the extremities of the digits of which a print is made.

In classifying the finger prints in the anthropometric files, use is made of those of the right hand only, and only of the first four fingers of that hand, viz., the thumb, index, middle, and ring finger. The little finger generally shows papillary patterns similar to its neighbor. Of course this resemblance is never complete, but for purposes of classification it is found expedient to refer only to the first four, which furnish enough combinations or "digital formulas" to enable the operator to sort the record-slips in the anthropometric boxes.

Where it is probable that marauders have touched the varnished furniture, or mirrors, or glassware, or objects covered with glossy paint, it is usual to attempt to discover their finger prints by dusting the surfaces with fine graphite (plumbago) or finely powdered white lead. In the first case the black powder will be fixed by the trace of greasy matter on the ridges of the finger. By blowing on the surface the superfluous powder not attached to such traces will be removed, and a fair—sometimes very distinct—print will appear of the arches, loops, and whorls, of the owner of the hand. This is photographed at a magnification of 4, 6, 8, or 10 diameters, depending upon the distinctness of the impression.

In using white lead, after removing the superfluous powder by blowing over the surface, the latter is exposed to the vapor of ammonium sulphide, which causes these traces to become black and thus permits of a photograph.

An interesting practical application of this method is beautifully shown in the December, 1908, number of the French "l'Illustration" in connection with a mysterious murder case (Steinheil–Japy) which has been agitating the capital since last summer. In this instance the invisible net-work of greasy exudation from the papillary ridges of various hands which grasped a bottle of cognac has been traced to the possessors of these hands.

Certain rules have been adopted to facilitate the sorting.

1. The type "e" is so designated no matter on what finger it may appear.

2. The record of the index is always given by the letters which describe its patterns whatever they may be, "e," "i," "o," or "u."

3. On the prints of the thumb, the middle, and the ring finger the types "i," "o," and "u" are designated by "x."

4. When an amputation (partial or entire), a deep wound (old or recent) obscures the form and number of the digital lines, it is customary to class the print of the finger or fingers as "u."

Thus the record slip of a subject whose right hand was amputated would be classified in the digital formula as "u," "u," "u," "u" which would be changed according to the rules above described into "x," "u," "x," "x."

The 32 digital formulas or combinations of prints classified in the equally numerous anthropometric boxes are all obtained from the four elements "e," "i," "o," "u," and with the assistance of the four rules before mentioned.

e e e e	x e e e
e e e x	x e e x
e e x e	x e x e
e e x x	x e x x
e i e e	x i e e
e i e x	x i e e
e i x e	x i x e
e i x x	x i x x
e o e e	x o e e
e o e x	x o e x
e o x e	x o x e
e o x x	x o x x
e u e e	x u e e
e u e x	x u e x
e u x e	x u x e
e u x x	x u x x

Sixteen formulas beginning with "e"; sixteen with "x"; eight each with a second letter "e", "i", "o", and "u" respectively; sixteen each with a third letter "e" or "x"; and sixteen each with a final letter "e" or "x."

I asked M. Bertillon to give me the record finger prints of a case in which this one of his many methods had been used with success to identify a prisoner, to exhibit to this audience, and he gave me the record of which I have made a lantern slide. On the 30th of April, 1906, a man was arrested and measured, who gave his name as Giard. He was numbered 346,503. It should be mentioned that M. Bertillon pays no attention to the way his subjects for measurement may spell the names they give as theirs, but solely to the sounds or phonetic values, and this was set down as above given. On the 4th of September, 1908, a

prisoner was measured and finger-printed, who gave his name as Giraut. He was numbered 374,242. During the two years and five months which had elapsed between the apprehension and measurement of these two prisoners 27,739 other prisoners had been subjected to the same ordeal in that place.

FIG. 14.

The search of files to discover whether this was an old offender brought in a few minutes this previous record. The agent in charge of the files went to the "e, u, e, e" case and produced a finger print which was compared with the second as you may compare them on the screen; the resemblance being so exact that it may be said no human being living or who ever did live could have produced the match to it. The man was identified at once.

Among the many names of criminals guilty of the atrocious Apache murders, highway robberies, parricide, and other horrible crimes which the daily Paris press recorded with disquieting regularity almost every day during September, I vaguely remember the name. He may not have been a murderer, but only the victim of a brain-storm during which he merely beat into insensibility and robbed his aged mother.

PHOTOGRAPHY.

The part of the service which has the most varied applications and which is directed by a most able assistant of M. Bertillon—M. David—is that of photography. In giving the general plan of the rooms devoted to the service of identification it was shown that the atelier, laboratories, and dark rooms are situated on the floor above that of the files and measurements. It is to this place that the subject of Bertillonage is brought after the osseous measurements, eye color, finger prints, and special marks are noted.

In the operating room, provided with all the necessary paraphernalia for regulating the light, is a little chair nicely pivoted on a small circular platform so that by touching a button the photographer can rotate it easily through 90 degrees, keeping the subject the while in perfect focus. The camera is fixed at the requisite distance to secure a negative one-seventh of nature. The subject is photographed so rapidly and with so little apparent effort that even the worst refractory has not time to think of distorting his features before he is photographed. But even if he maintain the most exaggerated distortion it will hardly perceptibly lessen the value of the print as a means of identification, for the features on which most stress is laid, the right ear and the nose, are not subject to movement at the possessor's will. Oftentimes indeed the attempt to disguise his features will result in bringing out some peculiarities of his anatomical structure which might otherwise have been missed.

Equally as important is the use M. Bertillon makes of his carefully prepared camera in taking projections and pictures of scenes and places when it is necessary to know the distances of objects apart.

By an original improvement in the peculiarly French art of iconometric photography, modified and improved, called by M. Bertillon his Photographie métrique, an interior of a room is so printed from a single negative that one can immediately ascertain the direction and distance of any point in the picture to any other; which of course is of incalculable value to magistrates and juries trying to learn the facts and surroundings of some crime.

A masterly exposition of M. Bertillon's inventions of apparatus and application of the principles of descriptive geometry has

just been issued by Dr. Louis Tomellini Privat Docent at the University of Genoa, called "Photographie métrique Système Bertillon," etc., Lyon A. Rey et Cie. 4 Rue Gentil. 1908, and sent to me from M. Bertillon's office.

This illustrated pamphlet gives drawings and descriptions of the camera and accessories employed in the service of identification, and the portable automatic camera which enables any photographer to take metric photographs which may be employed to produce prints in which distances and directions may be measured. Both cameras may be used to take photographs in the ordinary method on a vertical plane, or reversed on the tripod with the objective lens directed downwards.

The cameras are surmounted by two strips, one of which contains an eyehole and the other an aperture with cross-hairs, one of which is vertical and the other inclined 15 degrees with the horizon to adjust the oculo-tragian line. This arrangement produces the photograph of a subject, profile and face, at a reduction of one-seventh. A battery of objectives, prepared from M. Bertillon's indications, is called "of uniform impressions," with 10 cm. as its large angle. This battery is composed of three combinations obtained by changing the front lens. Combination N° 1 gives the maximum distinctness at 1.50 M. distance of the objective from the object; N° 2 at 2.50 M. distance, and N° 3 from 5 metres to infinity. Besides these, there is an aplanatic objective with a focus of 25 cm.

With the objective of 25 cm. focus the descriptive photograph is taken and printed to one-seventh natural size; the distance between the objective and the eye of the subject being two metres, conformably to the rules prescribed by M. Bertillon for his service.

The method for ascertaining distances and directions in these photographs is amply explained and illustrated in this pamphlet.

Stereometric photography is one adaptation by M. Bertillon which permits accurate measurements without determining the heights of the points of the object photographed (more frequently a corpse) above the floor. Two photographs are taken, the one, with the objective of the camera directed downward, the objective 1.65 M. above the floor; the other is a lateral view taken horizontally with the camera 15 cm. above the floor. The mean reduction of the view taken with the optical axis perpendicular to the floor is one-fifteenth because it is assumed that the medium plane of object (if a human body) will be 15 cm. above the floor and at 1.50 M. from the object photographed.

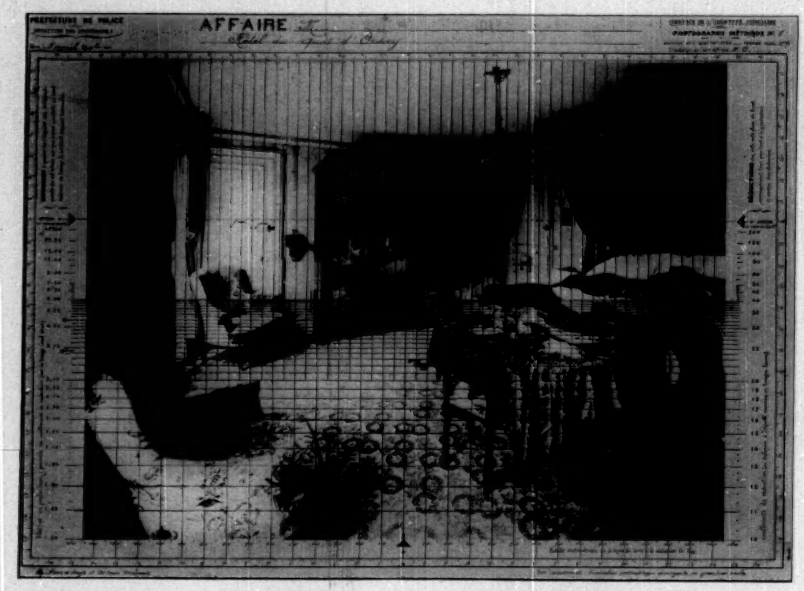
The following notes on iconometric photography, which is not the same process, by the way, but an older and in some respects inferior, are taken from the classical work of J. A. Flemer. "An elementary treatise on photographic methods and instruments," etc., John Wiley & Sons, London, Chapman & Hall, Limited, 1906.

"Under iconometry we understand the measuring of the dimensions of objects from their perspective views (Bildnisskunst).

"It refers to the plotting of terrene forms directly on the plotting sheet from the photographs of the landscape.

"If a photographic perspective of an object, the focal length ('distance line'), the second nodal point ('principal point') of

FIG. 15.



Metrically-photographed room of a recent murder on the Quai d'Orsay, where the actual distance and direction of every object in sight from every other object may be accurately ascertained.

the camera lens, and the horizon line of the perspective are given —if the point of view and the central projection of an object are given—these data will be insufficient for the determination of the object with reference to position and size.

"If, however, *two* such perspectives of the same object obtained from two suitably located stations be given, the dimensions of the object and its position with reference to the two stations may be determined iconometrically, very much in a manner analogous to that in which a point is located (by intersection or by the so-called radial method) on the plane-table sheet by being observed from two known plane-table stations. * * *

"The instruments for this purpose are called 'Photogrammeters' and the Art 'photogrammetry.'

"The foundation of what has now developed into a most important kind of automatic surveying by means of the camera, were laid by J. H. Lambert of Zürich in 1759, but found no echo in practical application till 1791–93 when Beautemps–Beaupré applied it while on a scientific expedition on the shores of Van Dieman's Land (Tasmania). On returning to France he attempted to construct topographic reconnaisance maps of the coastal regions from his free hand sketches.

"Long afterwards Capt. Le Blanc of the Engineer Corps in the French army employed it for military purposes.

"In 1839 while alluding to the details of the daguerrotype process before the Chamber of Deputies in Paris, Arago spoke of * * * 'les moyens rapides d'investigation que le topographe pourrait emprunter de le photographie' (the rapid means of investigation which the topographer could borrow from photography) * * *

"Gay Lussac expressed himself similarly.

"The first serious application was made by Col. A. Laussedat in 1850. Since then Capt. E. Deville, Surveyor General of Mineral Lands, Ottawa, Canada; Dr. W. F. King, Ottawa; Signore L. P. Paganini, Engineer Geographer of the Military Institute in Italy; Dr. R. Doergens, Royal Technical High School, Charlottenburg, Prussia, have done extensive work with the system. Mr. Flemer gives a partial bibliography of this subject:

"La Fototopografia in Italia, L. P. Paganini, Rivista Marittima, 1889.
"Nuovi Appanti di Fototografia id., 1894.
"Zeitschrift für Vermessungswesen, Stuttgart.
"Zeitschrift für Instrumentenkunde, Stuttgart.
"Lehrbuch der prakitschen Photographie, Dr. A. Miethe.
"Anthony's Photographic Journal.
"Die photographische Messkunst, Prof. E. Schiffner, Halle, 1892.
"Die Anwendung der Photographie in der prak. Messkunst, E. Dolezal, Halle, W. Knapp, 1896.
"Die Stereo-Photogrammetrie, Maj. von Auek. Mitth. des k. k. Mil-Geograph. Inst. XII, 1903.
"Photographic Surveying, E. Deville, Ottawa, 1895.
"Photogramatrie und Internationale Wolkenmessung, Dr. C. Koppe, Braunschweig, 1896.
"Comptes Rendus d l'Acad. de Sciences, Paris.
"Annales de l'Observatoire Météorologique du Mont Blanc, J. Vallot, Paris, 1896.
"Recherches sur les Instruments, les Methodes, et le Dessin Topographique, Col. A. Laussedat, Paris, 1898."

CLASSIFICATION OF DAILY SUBJECTS.

Of 80 to 100 individuals brought every day to the service of identification for measurement, 12 or 15 per cent. are women, and 5 per cent. under the age of 16.

Half of the number are old offenders who have already been measured; and for them it is only necessary to identify them, *i.e.*, to be assured that they correspond with this or that condition of life previously avowed, and are not usurping some other. The women do not take off any of their clothing and the osseous measures taken of them are in the first place less numerous than those taken of men, and in the second place are so chosen that the clothing does not at all impede the measurements.

The descriptive record of a man consists of—

1. The anthropometric, containing eleven osseous measures.
2. The data needed for the "portrait parlé."
3. The observations of special marks, cicatrices, etc.
4. The finger prints.
5. The photograph of full and side face at a reduction to one-seventh nature obtained by a special camera with automatic action.

WOMEN.

The description of a woman is composed of about the same elements as that of a man, except as to span, body measure, length and breadth of head (on account of the coiffure), of the foot, and of the elbow, altogether six measures less than for men. The reasons for this have been already intimated. For the same reasons particular marks of the breast, the back, forearm, and arm, are not taken. The measurer confines himself to such marks as are uncovered and visible on the face, the back of the hand, the fingers and the palm, up to the articulation of the wrist. So far as concerns the photograph, the finger prints, the portrait parlé, or the descriptive record, the procedure is identical with that followed for men. Although the osseous measures taken of the skeleton are less numerous for women than for men, yet the method of classification is as perfect for one sex as for the other.

In general it may be said that one can take almost an infinite number of osseous measurements from the skeleton of a subject, but not all with equal facility. Besides this there are measures

which though very valuable for purposes of identification offend against the sense of delicacy, and for that reason are rejected.

The present selection by Mr. Bertillon of parts to measure for anthropometric identification is recognized by the highest authorities in medicine and anthropometry as the best to combine ease of observation with the necessary importance for the object in view. It is fully admitted also that these selected measures are almost unchangeable from adult age to death.

PORTRAIT PARLÉ.

But the creation of M. Bertillon which is at once the most original and the most useful; which transforms in a few moments an ordinary guardian of the peace in a distant part of France by means of a telegraphic despatch into a detective agent able to recognize on sight a disguised malefactor whom he has never seen; the gem of the whole intricate system of Bertillonage is the "portrait parlé," or picture of essential features described in words.

To accomplish this a large code of abbreviations is necessary and a key to the meaning of the terms. Some of the most important of them have already been mentioned, but a word in explanation of their origin may be interesting. M. Bertillon thoroughly appreciates the value of a secret language known only to his operators, to stimulate their interest and to make of them a class apart. It is well too that his terms and methods should be concealed, as much as possible, from the criminal classes, which contain many bright minds that would take pleasure in thwarting him if they thoroughly understood all the observations on which he must perforce rely in his "instantaneous recognitions." Besides it is a short-hand which is rapidly written and translated.

He accomplishes three purposes in introducing and teaching to the police agents a kind of argot or dialect based upon abbreviations. He saves time and space, and he adds mystification to his work.

The thieves of every country have an argot or secret language, and it is advisable that the thief catchers should enjoy the same advantage.

But he spices this secret tongue with little catch-words which serve to fix the terms on the memory. For instance, a small

oblong pamphlet printed exclusively for the French police but of which he was good enough to give me a copy has the following title:

"Superintendency of detectives.—Service of judicial identification. Album D. K. V. of individuals subjected to interdiction of residence, escaped prisoners, and those sought for. Photographs at the Préfecture of Police, up to January 1, 1906.—Paris, Préfecture of Police, May, 1906."

The D. K. V. is a play upon words and is an allusion to three of his principal modes of dividing the description of the ear, viz.:

D–EQ, C–AR, VEX, which, he says, pronounced in succession, make three syllables, like Dé-ca-vé.

The first syllable D–EQ is composed of two parts—D–, descendant (descending), and Eq, Equerre (square, right angle). These are applied to the lobe of the ear, and are the two opposite extremes of the first characteristic which is observed.

C–AR is composed of the first two letters of "cave" for concave (concave), and R, rectiligne (straight); which are the two extremes noted in the possible position of the antitragus or interior border of the ear above the lobe.

VEX is for convex and only one of the characters used to describe the "pli inférieur" or interior vertical edge (antihelix) of the ear, the other being of course concave as with the lobe of the ear. But the syllables put together make the word décavé, a term used in gambling when a player has lost his entire "cave" or pile, and is said to be décavé, or "cleaned out."

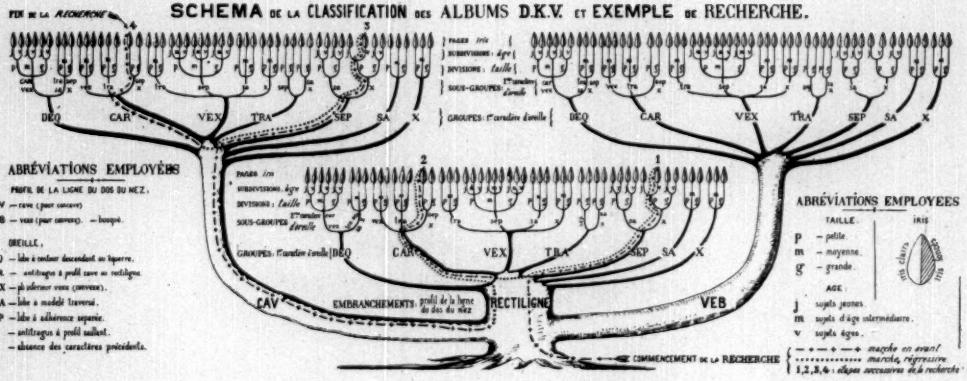
It seldom is applicable to the subjects for whom the system was invented, for they are usually fleeing with the possessions of others who, if living, are better examples of the décavés or depleted.

VEB is used for the equivalent of convex when the description is of the nose, because here M. Bertillon used two designations, one VEX (convex) for slightly aquiline, and busqué (hooked) for a very marked arch. He combines these two words by their initials VE– for vex and B– for busqué and calls the feature VEB.

A diagram illustrates the manner of searching in the album D. K. V. which may contain 3000 to 4000 photographs, for the identity of some suspected person whose nose, ear, height, apparent age, and eye color have been observed.

It represents a short-stemmed, low trunk with three principal divisions representing a concave, a straight, and a convex upper line of nose. It derives two characteristics from the ear affecting, first, the lobe, second, the lower fold or inner posterior vertical ridge. It then takes the height, the apparent age, and the color of the iris—six characters in all.

FIG. 16.


SCHEMA DE LA CLASSIFICATION DES ALBUMS D.K.V. ET EXEMPLE DE RECHERCHE.
FIN DE LA RECHERCHE
DEBUT DE LA RECHERCHE
PAGES iris
SUBDIVISIONS âge
DIVISIONS taille
SOUS-GROUPES 2e caractère d'oreille
GROUPES 1er caractère d'oreille
DEQ CAR VEX TRA SEP SA X
ABRÉVIATIONS EMPLOYÉES
PROFIL DE LA LIGNE DU DOS DU NEZ.
CAV — cave (pour concave).
VEB — vexe (pour convexe). — busqué.
OREILLE.
DEQ — lobe à contour descendant en équerre.
CAR — antitragus à profil cave ou rectiligne.
VEX — pli inférieur vexe (convexe).
TRA — lobe à modèle transversal.
SEP — lobe à adhérence séparée.
SA — antitragus à profil saillant.
X — absence des caractères précédents.
EMBRANCHEMENTS profil de la ligne du dos du nez
CAV
RECTILIGNE
VEB
ABRÉVIATIONS EMPLOYEES
TAILLE.
p — petite.
m — moyenne.
g — grande.
AGE.
j sujets jeunes.
m sujets d'âge intermédiaire.
v sujets âgés.
IRIS
marche en avant
marche, régression
1,2,3,4 : étapes successives de la recherche

This D. K. V. work is simply perfected detective work and is merely preliminary to the more careful research of the "cabriolets," as the rolling boxes in the anthropometric file rooms are called, for such indications as preclude the possibility of a mistake in identity. The D. K. V. albums, I presume, are manifolded and supplied to the principal French cities and especially those on the frontier, while if the escaping convicts have been measured, each of a number of agents of the police situated near the frontier is furnished with a small folded card, such as will be shortly shown to you, giving his physical description.

FIG. 17.

NOSE (See Fig. 17)

DEPTH OF ROOT

very small	small	rth small	medium	rth large	large	vy large

RIDGE

very cave cave sin	cave rect sin	rth cave vex sin	rectil arched sin	rth vex sl arched	vex arched	very vex much arched

BASE (TIP)

very pug	pug	rth pug	hrzn	rth depr	depr	much depr

HEIGHT

very small	small	rth small	medium	rth large	large	vy large

PROTUBERANCE (See Fig. 18)

very small	small	rth small	medium	rth large	large	vy large

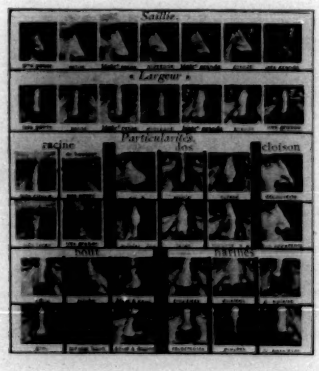
BREADTH

very small	small	rth small	medium	rth large	large	vy large

ROOT		PECULIARITIES			RIDGE	
vy narrow vy broad	height vy small vy long	sigmoid (saddle) flat crv	thin broad	crushed cvd to r	septum visible septum not visible	

POINT				NOSTRILS	
thin large	bi-nodular end flat	incl left incl right	adh recur	dilated comprsed	flat l rt raised

FIG. 18.



RIGHT EAR—*General Diagram*

BORDER (See Fig. 19)

ORIGINAL BORDER-LENGTH

zero	small	rth small	medium	rth large	large	vy large

UPPER BORDER. BREADTH OF RIM

flat	small	rth small	medium	rth large	large	vy large

POSTERIOR BORDER. BREADTH OF RIM

flat	small	rth small	medium	rth large	large	vy large

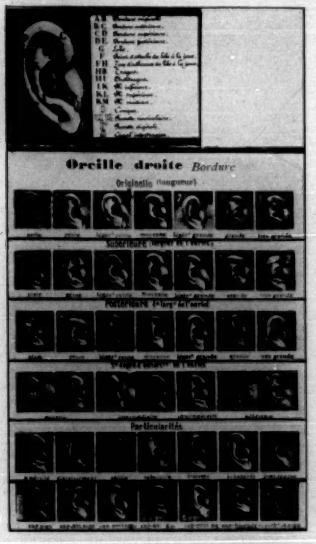
POSTERIOR BORDER. DISCONNECTION OF RIM

open	open	interm	interm	intermed	adherent

PECULIARITIES

Nodosity	enla'ge'nt	protub	tuberc	crumpled	grooved	post sheared
sup'pntd	sup-ant pntd	sup-post pntd	sup-ant square	sup-post square	sup bi-folded	sup-obt-ang

FIG. 19.



RIGHT EAR

LOBE (See Fig. 20)

CONTOUR

incl downward	desc forms square	square	square inter (?)	square intdesc	intermediate	gulf

ADHERENCE TO CHEEK

sheared	sheared	sl shrd	interm	sl sep	separated	separated

MODELLING

furrowed	furrowed	sl furd	interm	unified	eminent

HEIGHT

vy small	small	rth small	medium	sl large	large	vy large

PECULIARITIES

bored	split	narrow	broad	dimpled	comma shpd	islet
oblique-intern		oblique	extern	anterior-torsion		post obl wrinkle

RIGHT EAR

ANTITRAGUS (See Fig. 21)

INCLINATION

horizontal	horizont	rth horiz	interm	sl oblique	oblique	vy oblique

PROFILE

concave	rect	sl rect	interm	sl protub	protub	vy protub

"RENVERSEMENT." Change of plane (?)

plane-twisted	intermediate	straight

VOLUME

zero	small	rth small	medium	rth large	large	vy large

PECULIARITIES			PROFILE	PECULIARITIES		
fusion with border	tragus pointed	tragus bifurc	combination inclination oblique horizontal	cave	rect	protub
incision post-ant	canal narrow	dimple naviclr pt		cave	rect	protub

FIG. 20.

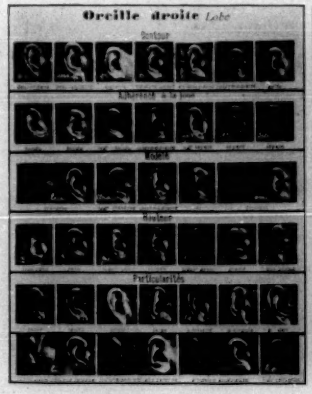
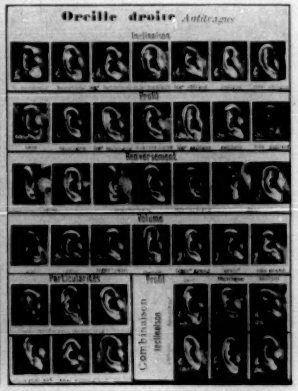


FIG. 21.



RIGHT EAR

FOLDS AND GENERAL FORM

LOWER FOLD

vy cave	cave	rth cave	interm	rth vex	vex	very vex

UPPER FOLD

zero	effaced	rth efcd	interm	rth mrkd	mrkd	very marked

GENERAL FORM

triangular	rectangular	oval	round

SEPARATION FROM SKULL

upper	back	lower	entire or pedunculous	at abv sep bel	brkn a'ry

PECULIARITIES

up fld brnchd	un to brd	r hematome	mid fld hgh	orig contin	orig sep	inser vert
cnq low	cnq high	cnq nar	cnq broad	cnq trnd back	cnq trvsd	inser obt

CORPULENCE (See Fig. 22)

NECK		PECULIARITIES	SET OF SHOULDERS INCLINATION
short long	thin fat	larynx prominent double chin goitre	horizontal oblique

FIG. 22.

HEAD AND FACE—*General View*

GENERAL CONTOUR OF THE HEAD

VIEW OF THE PROFILE. PROFILE FRONT-NASAL

contin	brkn	paral		ang	arched	undul

PROFILE NASO-BUCAL — SYNTHETIC

prtb dentl	nose bone protub	up progn up orthgn	low progn compl orthgn	compl progn inwd cav		half moon pinion

HEIGHT OF CROWN			CRANIAL PECULIARITIES			
low	high		flat occpt	rnd occpt	tufted	keel shpd

VIEW OF THE FACE

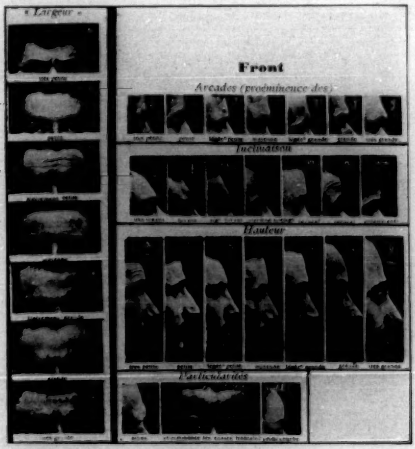
SYNTHETICALLY

top slip square	lozng broad	pyram round	bi-cave rectang	asym long	

ANALYTICALLY

sep parict comprsd par	sep zygom comprsd zyg	sep jaws comprsd jaws	chk bns prtb flabby chks	full face bony face	

FIG. 23.



HEAD

FOREHEAD (See Fig. 23)

ARCHES OF EYEBROWS

very small	small	rather small	medium	rather large	large	very large

INCLINATION

vy rtrng	rtrng	rth rtrng	interm	rth vert	vert	prominent

HEIGHT

very small	small	rather small	medium	rather large	large	very large

PECULIARITIES

sinus		promin of temples	curved profile	

BREADTH

very small	small	rather small	medium	rather large	large	very large

HEAD

WRINKLES (See Fig. 24)

FRONTAL	BETWEEN EYEBROWS	VARIOUS
entire	vert and medium	temporal
medial	vert unilat l	tragian
curved	oblique to r	naso-labial
arched	hzl fr root of nose	jugular
rectil	circumflex	vert on neck
sinuous	triangular	occip pad

FIG. 24.

HEAD

EYEBROWS (See Fig. 25.)

SETTING	FORM	PECULIARITIES OF IMPLANT
close together	much arched	sparse
separated	rectilinear	sparse in tufts
low	sinuous	profuse
high	short	joined together
direction	long	maximum in tufts
oblique inwardly	narrow	bushy
oblique externally	broad	painter's brush

HEAD

EYELIDS	EYEBALL		SOCKETS
dimensions of opening	peculiarities	protuberant	
	HORIZONTALLY		
small	eyes bridled	small deep set	high
large	up l falling	large protub	low

VERTICALLY

small slty opened large very open	extern extrusion compl extrusion	peculiarities much raised	deep full

UPPER

modelling covered apparent extern ang dprsd	lower as pads lower as pocket low wrinkled r reversed	strbsm converg strb r converg strb l divg	interocular small large

FIG. 25.

HEAD

CHIN

INCLINATION			HEIGHT	
retreating	protuberant	«	small	large

BREADTH			PECULIARITIES	
small pointed	large square		flat	crested

PECULIARITIES				
dimple	long dimple	bi-nudular	prom furrow	above chin

HAIR

FRONTAL INSERTION		BALDNESS
circular rectangular in points mounting		frontal temporal fronto-parietal

HEAD

LIPS

NASO-LABIAL	HEIGHT		PROMINENCE	
small	large		upper	lower
		BORDER		
small	large		small thin	large thick
LACK OF ADHERENCE			PECULIARITIES	
up turned up	low pend	med trough prom	cracked	cic hare lip

MOUTH

		DIMENSION		
small	large		pinched	open
		PECULIARITIES		
corners raised	corners depress	r corn dprsd	oblique to r	
SYNTHETICALLY			DENTITION	
heart shod mouth	thick lipped	incisors visible	incisors protub	

This most important branch of the French police work is thoroughly prepared and brought to a high state of efficiency. In one of the suites of rooms in the Palace of Justice set apart to the service of identification is a rostrum with blackboard and mounted sheets containing life-size photographs of the types which are here presented.

There are three courses of instruction annually, each lasting three months, and consisting of thirty lessons of an hour and a half each. All the policemen of the prefecture of police, of the general safety, and of the ministry of the interior are obliged to complete this course in order to obtain their appointments.

The examinations at the end of each course are threefold: first, written, second, oral, third, practical test in the courtyard of the préfecture.

Besides the policemen taking this course are many physicians, lawyers, municipal guardsmen, republican guardsmen, judges, and many foreigners.

M. Bertillon has adopted as the motto of this school of instruction, and caused it to be painted on the rear wall, the following aphorism of his father.

"The Eye Sees in Objects Only What it Regards There, and it Regards Only What is Already in Idea in the Mind."

The practical exercise at the beginning of the course of description consists in trying to find among sixty small photo-

graphs the one or more which may be coupled with one of six life-size heads which the professor places in front of each scholar. The six large photographs have striking resemblances to certain of the smaller photographs, though their respective subjects were entirely unrelated.

The scholars always fall into the trap laid for them at the first trial which impresses upon them the necessity of depending upon the scientific method in drawing their conclusions. On the first trial the erroneous judgments are quite 80 per cent. At the conclusion of the course *there is not a single one made.*

At the commencement of the course, ignorant of the organs which should be scrutinized, and of the different points of view from which they should be examined they rely on striking resemblances, and on characters without value, such as the beard and the hair which the razor or the scissors can entirely change in an instant.

In the collection of sixty small photographs are two or three which ought to be connected with each of the large heads, but they are always missed at the commencement of the course because superficially they are so dissimilar in general aspect.

As an example of the changes to be expected after the lapse of a few years in the general appearance of an individual of the criminal classes the subjoined pictures are very instructive. It must be remembered that in Bertillonage the unit picture is the profile and full face, which are always coupled together.

It will be observed that each couple has a number affixed to some part of the picture, those of the left-hand double column having simple numbers and those of the right hand double column having numbers to which is attached "bis." If each couple were detached from the rest and lying on a table with sixty other detached couples, it is very improbable that any one could, by the usual method of superficial appearance, join to each of the five numbers of the left-hand double column the couple which represented the same man a few years later. But by the application of the Bertillon method the task is easy. Every couple of this series in the left-hand double column is of an individual who is represented a few years older on the same line in the right-hand double column, the photograph bearing the same number "bis."

The double couple marked "Job" and "Malib" is even more remarkable. The left-hand couple represents the appear-

FIG. 26.

ance of prisoner 264,338 on July 18, 1896. The right-hand couple represents the same man as 314,915 on Nov. 22, 1901.

The last double couple is still more remarkable. The left-hand couple represents one Péron arrested Nov. 28, 1897, and

FIG. 27a. FIG. 27b.

numbered 280,032; the right-hand couple represents Taran, an entirely different person, arrested the same day and the fourth person photographed after the negative of Péron was obtained. There is no relationship between them yet the general resemblance is striking. Any supposed identity immediately disappears

FIG. 28a. FIG. 28b.

if one scan closely the profiles of the noses and the structure of the ears.

The illustrated lectures and quizzes are conducted by M. Bertillon's representative, M. Marius Bertrand.

In addition to learning the anatomical names of the regions of the body employed in measurements, the meaning of very

small, small, slightly small, medium, slightly large, large, and very large, as applied to the parts or the whole of these parts, they are instructed in the work of identification by means of a large number of "carte-de-visite" photographs which have been most ingeniously selected by M. Bertillon. These represent many score of individuals and among them the same person undisguised and in one or more disguises; with and without beard, moustache, hair on his head, etc. But there are other pitfalls for the unwary in the form of pictures of persons in no way related to each other and yet so like that the ordinary observer would

FIG. 29.

hardly fail to call them the same person. Here is where a test is made of the efficacy of the lessons which M. Bertrand so carefully impresses on his classes: attention to the form and peculiarities of the nose, ear, height, age, and eye.

I was almost always deceived by the general appearance when a number of photographs were thrown on the table and I was asked to select two of the same person. Yet when these features in the two similar pictures were compared it was apparent that the contour of nose, or of ear, etc., were not alike, and on the other hand when the often very dissimilar-looking pictures of the same person were found for me I recognized a similarity in these little "ear marks" though the whole aspect of the face was so

utterly unlike that I never should have suspected that the originals were the same person. The photographs taken for the portrait parlé are always a front and a side view; but the latter is of the greater value because in it one can determine the characteristics of nose and ear. The full face is important in those cases where there is no disguise and also to serve as a means of comparison where an ordinary photograph of a missing culprit can be obtained, because these ordinary photographs are usually full face or nearly so.

Another and still more useful practical exercise must be successfully accomplished in order that the policeman-scholar shall have a good rating. At the hour of noon a recess is taken by

FIG. 30a. FIG. 30b.

the employés of the Palais de Justice, and in a courtyard of the Palace of Justice the students of identification may be seen each carrying a little slip, the portrait parlé, and endeavoring to identify some colleague of which it bears the description. This is an ideal place and time to test the astuteness of the student-detectives.

To each of a class is given a portrait parlé of some other member who has been described for the purpose (often without his knowledge), and who it is known will be among the throng.

Each recipient of such a portrait parlé (without the photograph) is required to find the subject and to "arrest" him—at least to ascertain his name within the half hour. M. Bertrand informs me that though this is very difficult at first for the neophytes, in a very short time—a few weeks—they become so adept that scarcely a case escapes them. This of itself speaks volumes for the efficacy of the method.

DIAGRAM OF RECOGNITIONS MADE BY THE SERVICE OF JUDICIAL IDENTIFICATION FROM 1883 TO 1907 INCLUSIVE.

Years	Number of recognitions of prisoners		Total number of recognitions
	In Paris	In the provinces or in foreign lands	
1883	49	....	49
1884	241	....	241
1885	425	....	425
1886	356	....	356
1887	487	....	487
1888	534	16	550
1889	538	24	562
1890	614	27	641
1891	600	41	641
1892	617	65	682
1893	527	65	592
1894	480	133	613
1895	414	153	567
1896	447	204	651
1897	371	218	589
1898	340	231	571
1899	363	264	627
1900	311	250	561
1901	389	288	677
1902	464	400	864
1903	361	418	779
1904	446	501	947
1905	456	517	973
1906	456	566	1022
1907	355	604	959
Total	10,641	4,985	15,626

Another and very valuable application of the records of the service of identification has been made in Paris for some years past, viz., the identification of the unrecognized dead in the morgue. There is a fatal connection between a life of crime and a death which brings the victim's body to the morgue, and it is often most valuable to the public safety to know when an unusually dangerous criminal is dead. A few days ago I received from M. Bertillon's office the profile-full-face picture belonging to the record of a criminal named Garraud who was arrested, measured, and numbered on Nov. 19, 1884, this being his first record of arrest. In April, 1900, an unknown body without papers in the clothing, or other means of identifying it was exposed in the morgue for the usual time without having been recognized by any of the visitors. The anthropometric service was then called upon

to measure and photograph the corpse. With the aid of a few measures the clerk was able to find in the anthropometric file boxes a record slip with photograph bearing the number 83,268 (he was of the year 1900—219 at the morgue). The waif was recognized as Garraud, his history at that date was revealed, and the authorities of his district of Paris reported it to his relatives, who gave him decent burial.

The number of such recognitions in the morgue was in 1902, 10, 1903, 6, 1904, 3, 1905, 13, 1906, 19, 1907, 5, and 1908, 21.

Four squads of two agents each suffice to Bertillonize 100 persons before noon.

The criminals themselves are beginning to recognize the fact that it is useless to persist in asserting a false identity, and, if they have been measured before, frequently change the previous statement of their name and occupation on reaching the apartments of the service of identification before any measurement is *begun*. What facilitates this is a night of detention after their arrest and the consequent time to reflect.

> These cases have made an additional heading necessary in the files, which is called "recognized as having been measured before." They are entered thereunder as soon as their confession has been proved by a test with the head callipers. The number in this class actually exceeds those recognized against their will.

The latter show the number of persons who before the adoption of Bertillonage succeeded at their trials in masquerading as first offenders though in fact old offenders.

Another fact proving the efficiency of Bertillonage is the diminution of the number of persons recognized in prison as old offenders. Where there were 200 to 300 in number in 1884–85, in 1888 there were only 14, of whom ten had never been measured by the Bertillon system. Only 4 out of 31,000 succeeded in evading the vigilance of the Bertillon agents in that remote year, and there have been fewer ever since; so that it may be assumed that practically no one escapes the Bertillon scrutiny to-day.

MOTIVES FOR FALSIFYING NAMES.

The motives which induce old offenders to change their names are first of course not to have their past record in addition to their present offence to answer. Besides there are many who are deserters from the military service, or refractories who are especially anxious not to be relegated to the military authorities.

Certain kinds of criminals seem more inclined than others to give a false name. In the front rank, says M. Bertillon, are the Anglo-Saxon pick-pockets. All of these gentry think it necessary to lie about their identity. The result has been that since the establishment of the service, the number of pick-pockets arrested has constantly diminished. In 1885 it was 65, in 1886 it fell to 52, in 1887, to 34, and in 1888 to 19.

Many of the borrowed names are manufactured entirely and have no relation to any actual being. But among the names borrowed the greater number are the family names of the culprits' mothers before marriage. Others maintain their real surname but take the given name of a brother. In this case it is often found that data of many of the measurements closely approach those of the persons they have honored by selection to suffer for their sins; and cicatrices and special marks are relied upon to establish the actual fact.

It sometimes though less frequently happens that an evildoer arrested for the first time gives a false name, condition, and occupation, to avoid the scandal which would rest upon his family. And that leads to a proposition of M. Bertillon which is perhaps the most important suggested by his system.

If the identification be so perfected, and so universally adopted, that recognition of a person who has been Bertillonized is positively certain, will it not be possible to so modify the penal legislation that the trials and condemnations of criminals shall proceed to their ultimate punishment of the guilty without the use of names at all? In this way the innocent parents, brothers and sisters of a degenerate may be spared the added humiliation and suffering of seeing the name they bear, and have tried to make honorable, associated with some revolting or contemptible crime. Of what use from a penological point of view is it that Leon Czolgosz is published through the world as a murderer if the fiend who had that name has been caught, tried, condemned, and executed?

May not the discouragement produced upon a family of grown-up brothers and sisters who have been too long known in the community to renounce a name one of them has made infamous, lead to the descent of the others into crime?

Just as Newton's proof of the laws of the revolution of the planets was the result of putting together and combining formulas

long before known; just as "Paradise Lost" was constructed by juxtaposing English words at the command of the poorest subject of the British Kingdom or Commonwealth; just as Napoleon's victories were won by putting into unwonted relations to each other the ordinary laws of war known since the time of Julius Cæsar; so M. Bertillon's service has been to construct out of old, well known materials the most powerful engine for the detection of criminals, and therefore the arrest of crime, which ever has been devised.

The extent of the debt to him of civilized communities is not lessened from the fact that like all engines this one needs careful and patient study by intelligent men to make it effective.

OVER-CUTTING OF CONNECTICUT'S FORESTS INDICATES GENERAL RATE OF TIMBER CONSUMPTION.

It has been estimated that the amount of wood annually consumed in the United States at the present time is twenty-three billion cubic feet, while the growth of the forest is only seven billion feet. In other words, Americans all over the country are using more than three times as much wood as the forests are producing. The figures are based upon a large number of State and local reports collected by the government and upon actual measurements.

The State Forester of Connecticut, in a recent report, has given figures on growth and use for New Haven County, which give many more valuable details than are generally to be obtained, and well illustrate how the forest is being reduced by over-cutting. In this county a very careful study was made on each township of the amount of forest, the rate of growth, and the amount of timber used. For the year 1907 the timber used was 120,000 cords, in the form of cordwood, lumber, ties, poles, and piles. The annual growth on all types of forest land, including the trees standing on abandoned fields, for the year, reached a total of 70,000 cords. Thus the amount cut yearly exceeds the growth by 50,000 cords.

The amount of standing timber considered as merchantable and available for cutting within the next few years was found to be 1,200,000 cords. Each year the annual growth increases the supply on hand by 70,000 cords, while the use decreases it by 120,000. The net reduction is therefore 50,000 cords a year. If the cut and the growth remain at the present figures, the supply of merchantable timber will be exhausted in about twenty years. At the end of that time there will be a large amount of forest standing in the county, but it will be in tracts under forty years of age, containing wood below the most profitable size for cutting. Cordwood could still be cut, but supplies of the most profitable products, like ties and lumber, would be practically exhausted.

Connecticut's case illustrates what is meant when the exhaustion of the timber supply is spoken of. It does not mean that every tree will be cut and that the ground will be bare. It means, on the other hand, that year by year the people of the country are cutting more timber than the forest grows, and that within a comparatively short time the continued loss will have so reduced the forest that it will be difficult and expensive to obtain timber of useful size in sufficient quantity.

P. Curie

M. Curie

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FRANKLIN INSTITUTE

THE DISCOVERY OF RADIUM.

[Report of the Franklin Institute, through its Committee on Science and the Arts, on the researches by which Professor and Madame Curie were led to the discovery of radium. Subcommittee: Harry F. Keller, chairman; William J. Hammer, George F. Stradling, Robert H. Bradbury, Arthur J. Rowland, H. Clyde Snook. No. 2413.]

THE year 1895, in which were published Lenard's experiments on the cathode rays and Röntgen's discovery of the X-rays, may be said to mark the beginning of a new and most fruitful period in physical science. The first decade of this period will ever be memorable for great achievements, both in the discovery of new facts and in the framing of hypotheses, which have so materially advanced our knowledge of the constitution of matter. Among the experimental researches of this period none, perhaps, will stand out more conspicuously than those which have brought to light the carriers of radio-activity and which have culminated in the discovery and separation of that most powerfully radio-active element, radium. It seems hardly within the scope of this report to review, even briefly, the very numerous discoveries, made by a host of investigators working in widely different fields, which prepared the way for the experimental inquiries of Professor and Madame Curie; but the starting-point of these researches was the discovery in 1896, by the late Henri Becquerel, of those wonderful radiations which their discoverer called uranium rays, and which, under the more fitting name of Becquerel rays, we now regard as a manifestation of radio-activity.

A study of the phosphorescence of certain uranium salts, such as the double sulphate of ammonium or potassium and uranium, led Mme. Curie to undertake a systematic examination of other substances for Becquerel rays, and she found that thorium compounds also emit them. Quantitative determinations of the radio-activity of various uranium and thorium minerals then disclosed the fact that this property was not proportional to their uranium or thorium contents, and that some of the minerals were indeed several times as radio-active as the free elements. Having

ascertained that the radio-activity of uranium is an atomic property, *i.e.*, a property not affected by combination with other elements, Mme. Curie argued that strongly radio-active minerals, like pitchblende, must contain some unknown substance of greatly superior radio-activity, and, joining forces with her husband, the late Pierre Curie, she proceeded to search for the hypothetical constituent. The Austrian Government aided the investigators by placing at their disposal a ton of uranium residues from the Imperial factory at Joachimsthal, and it was from this material that, by means of suitable analytical processes and guided by the extremely sensitive indications of the gold-leaf electroscope, the Curies succeeded in separating, first, the highly radio-active substance which they named polonium, and, later, in conjunction with M. Bémont, the still more active body which they so happily christened radium. Although other radio-active substances, notably Debierne's actinium and Boltwood's ionium, have since been extracted from uranium and thorium minerals by other investigators, radium still remains the only one that has been characterized as a chemical element, and, while it has not as yet been obtained in the free or elemental state, it has been isolated in the form of pure salts, such as the chloride, bromide, sulphate, and carbonate. Its analytical behavior and other chemical properties were found to be those of the alkaline earth family of elements, and its place in this group was confirmed by Mme. Curie's repeated determinations of its atomic weight, and by a careful study of its spectrum by Demarçay, Runge, and others.

In addition to the separation and investigation of the radio-active constituents of pitchblende the Curies have made a most elaborate study of the radiations of these bodies, of the various physical, chemical, and physiological effects which the latter produce on other substances and on living tissues, and of the tremendous energy which is manifested in the spontaneous transformations of radium.

The committee charged with the preparation of this report on Professor and Madame Curie's work on radio-active substances is of the opinion that it constitutes one of the classical researches in physical science, and that its principal result, the discovery and characterization of radium, is without doubt a scientific achievement of the first magnitude. This estimate the committee bases mainly on the following considerations, viz., in

the first place, that only a bold scientific imagination could have conceived the idea of instituting the quest for an unknown radio-active constituent of the uranium minerals; secondly, that one cannot help but be deeply impressed with the brilliancy of the method of research which combined an entirely novel analytical agent—the ionization of air—with a masterful selection and combination of known chemical reactions; thirdly, that the work could not have been carried to its successful conclusion without the rare skill, the sound judgment, and the extraordinary perseverance displayed by the investigators; and fourthly, that the discovery of the carriers of radio-activity has placed at the command of scientists a new source of energy which has already been instrumental in opening up most fruitful avenues of research in a previously untrodden field. Without in any way detracting from the value of the splendid contributions to our knowledge of radio-activity which we owe to Rutherford, Elster and Geitel, Ramsay, Giesel, Soddy, Boltwood, and many others, it is safe to say that if it had not been for the epoch-making researches of the Curies, we would still be ignorant of the immensely powerful emanations of radium and thorium, of the transformation of radium emanation into helium, of the apparent degradation of elements of large atomic mass into others of smaller atomic mass, of the differences in the character and effect of the several kinds of radiations and emanations emitted by radio-active bodies, and, further, the numerous applications of radio-activity to biological, medical, geological, and cosmic problems which have been recorded, would not have been made in our time.

In view, then, of the invaluable services which Professor and Mme. Curie have rendered to science, the committee recommends that the highest award of the Franklin Institute, the Elliott Cresson Medal, be bestowed upon Mme. Sklodowska Curie of Paris, as a recognition of her share in this work, and as a tribute to the memory of her lamented husband, Pierre Curie, whose indefatigable co-operation so largely contributed to its success.

Attest: JAMES CHRISTIE,
Secretary.

PHILADELPHIA, January 6, 1909.

SECTION OF PHYSICS AND CHEMISTRY

(Stated meeting held Thursday, December 10, 1908.)

THE THEORY AND PRACTICE OF ILLUMINATION.

BY
THOMAS W. ROLPH.

In any branch of engineering, practice usually precedes theory. As practice develops and becomes more wide-spread, its faults show themselves, and in the attempt to remedy these faults the theory is evolved. Theory reacts upon practice, improving it, and practice in turn reacts upon theory, causing a development of shorter methods of predetermining results.

Thus, in the field of illumination practice is several thousand years old, but the theory is only beginning to be developed. The development of the early forms of illumination was not accompanied by any great increase in intrinsic brilliancy or intensity of light per square inch of lighting surface. The fire brand of the savage naturally led to the use of the pine torch for illumination. This in turn was succeeded by candles and oil lamps. Until the introduction of illuminants more efficient than these, the intrinsic brilliancy of the light-source remained very low. The quantity of light which could be obtained from a single light-source also remained low, and to illuminate large areas large numbers of light-sources were necessary. It was a simple matter to place these lights where desired. With the development of gas and electric lights, whose locations are more or less permanent, faults of location began to be apparent. Candles or oil lamps could be moved to the part of the room in which the light was wanted. For example in a bed room they could be placed near the mirror when it was in use. Generally speaking this is impracticable with gas and electricity, however, and in order to obtain the light at the proper points, it is necessary to either flood the room with light or to locate the lights where light is desired. The former is undesirable from the standpoint of economy, and hence arose the study of light location as a part of the work of the designer

of lighting systems. Another important factor in the development of illumination was the decreased cost of the production of light, which led to a wider use and therefore raised the standard of illumination. Consequently the use of lights with regard to efficiency of operation and the placement of lights with regard to uniformity of illumination attracted the attention of the workers in the field.

At this point theory of illumination began to be developed. Methods of changing the natural distribution of light-sources were introduced; then methods of measuring the intensity of light and of calculating the amount of light necessary to obtain the required illumination, were brought out. The early calculations were necessarily laborious and were, therefore, not widely applied. Improvements have been made, but it is only within the last two or three years that these improvements have shortened the methods of calculations sufficiently to cause their widespread application. Conditions are now such that it is a commercial proposition to apply illumination calculations to practically every problem of any size. The conditions of lighting in this country are, therefore, gradually improving, although it is no exaggeration to say that over half of the lighting systems in use to-day could have their efficiency materially increased without in any way detracting from the artistic results obtained. This is due both to the increased efficiency of modern illuminants themselves, and to improvement in the location and equipment of them.

In considering the theory of illumination, we must first consider the purpose of illumination. Its principal object is to enable the eye to see comfortably the objects illuminated. Here at once we perceive two factors: first, the human organ upon which the effect is produced, viz., the eye; second, the factor which produces this physiological effect, viz., light.

Considering light first, it may be defined as those particular vibrations of the ether whose wave-lengths measure between .00004 of a centimetre and .00008 of a centimetre. The visible spectrum lies between these limits, the violet rays being the shortest and the red rays the longest. When the colors composing this spectrum are combined in about the same proportions, as in day-light, the effect upon the eye is that of white light. This is the combination of colors ordinarily striven for in artificial light-sources.

Light itself is invisible, and by this is meant that we cannot see light rays unless they pass into the eye. For example, the beam of a search-light would be absolutely invisible when viewed from the side, were it not for slight particles of dust in the air which reflect portions of this beam back to the eye. To see any object, then, we must have light falling upon this object and reflected from it to the eye.

Illumination as a branch of engineering is peculiarly distinctive inasmuch as it involves effects upon a human organ. To understand the problem, we must consider the construction of this organ. Fig. 7 is a rough drawing of the construction of the eye. It is similar to a camera. In the figure, *i* is the iris or diaphragm which forms the colored portion of the eye; *p* is the pupil, or opening through which light passes; *l* is the lens for focussing the picture; *r* is the retina and corresponds to the plate or film of the camera. The central portion is called the vitreous humor and consists of a transparent fluid filling the inner portion of the eye, and serving to maintain the shape of the eye. The action of both the lens and the iris is automatic. The muscles moving the lens automatically focus the object to be seen, upon the retina. In the eye this focussing is accomplished by changing the shape and consequently the focal length of the lens. In a camera the focal length of the lens never changes and focussing is accomplished by a change in the distance from the lens to the plate or film. The iris determines the amount of light to be allowed to pass into the eye. It corresponds to the stops of a camera. For example, when the light becomes very intense the iris automatically closes as far as possible. Photographers know that the smaller the stop in the camera the sharper the definition will be in the picture. This is also true of the eye. When the illumination is very low and objects are dimly lighted, the iris is open to its widest extent, to allow as much light as possible to pass in. The outlines of objects are then indistinct and hazy, showing that they are not focussed perfectly upon the retina. Brilliantly illuminated objects, on the contrary, stand out very sharply and distinctly. This does not mean, however, that a bright object such as a filament of an electric lamp would stand out distinctly, for here the brilliancy is so great that the iris shuts out as much light as it can, and yet cannot shut out enough to prevent a strain of the retina and consequently poor vision.

For the protection of the eye there are several points which should be considered in designing lighting systems. The following are the most common causes of injurious effects:

1. Too little light.
2. Too much light.
3. Glare.
4. Flickering.
5. Streaks or striations.
6. Extreme contrasts.
7. Reflection from polished surfaces.

The first two of these are easily taken care of by the calculations of the engineer.

Glare is a common fault in lighting systems, and it has worked untold injury to the eye. Witness in theatres and public halls the many lighting systems with bare lamps directly in the field of vision and often so arranged that the audience must look past or nearly at them in order to see the stage or platform. Some of these systems of lighting appear to have been designed with the special object of adding to the prosperity of the oculist. Two simple considerations will be the means of eliminating these injuries. First, keep the light-sources as far as possible above the direct range of vision—no economy is sacrificed by this, if correct reflectors are used. Second, diffuse by a globe or reflector the light from sources of high intrinsic brilliancy.

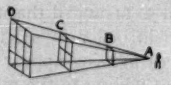
It was previously stated that the action of the iris of the eye is automatic. In its motion, however, there is an appreciable time factor and a change in the intensity of the illumination on a surface does not cause an instantaneous change in the size of the pupil. Herein lies the injury worked by a flickering light-source, for before the eye can adjust itself to a given intensity of illumination, the intensity has changed. The most common example of flickering is the ordinary arc lamp.

Streaks or striations are caused by reflection from a polished metal surface. A polished aluminum reflector will produce brilliant streaks on a surface illuminated by it. The attempt of the eye to adapt itself to two conditions of illumination at the same time, cannot fail to be harmful.

An illustration of eye strain caused by contrasts is in the illumination of a book-keeper's desk. It is not uncommon to find

a light source with a concentrating reflector, brilliantly illuminating one book, while another book continually referred to, is supposed to be illuminated by the same light. The quantity of light on either book may be sufficient for comfortable vision, but the necessity of a continual change in the size of the iris is a strain on the muscles. Reflection from polished surfaces is regular reflection. By regular reflection is meant the direct reflection of light. The extreme case of regular reflection is that of mirrors, but any glazed paper causes it and only a very rough surface, such as blotting paper, does not give some direct reflection. Unless the light is properly placed, this causes a brilliant spot on the paper worked upon, and consequent injury to the eye. In desk lighting this can be avoided by placing the light-sources not in the middle of the desk or directly in front, but at the left.

FIG. 1.



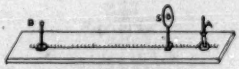
Law of inverse squares.

The desirability of obtaining the correct intensity and distribution of illumination and of obtaining this in an efficient manner, necessitates the use of lighting calculations. In considering these calculations, we must first consider the fundamental units of light and illumination. Of these, the most widely used is the candlepower or unit of intensity of light. It should not be confused with quantity or with any idea of distance. If a lamp gives a certain candlepower in any particular direction, the candlepower is the same no matter what the distance may be. It is not intensity of light, but illumination which is affected by distance from the light. The unit of quantity or flux of light is the lumen. A third unit in common use is the unit flux-density or intensity of illumination, and is the foot-candle. Flux-density varies inversely as the square of the distance from the light-source when the latter is a point. This is illustrated in Fig. 1.

The emission of light from a point may be considered analogous to a spreading stream of water issuing from the nozzle of a hose and affected by no other forces. Since there are no

other forces acting, each particle will travel indefinitely in the same direction. Candlepower of light is analogous to the speed or velocity of the water. It is the same at all distances from the nozzle or light-source. Flux or quantity of light is analogous to the quantity of water which the nozzle sends out in a unit of time. This is also a constant quantity for any particular condition of flow. Flux-density is analogous to the quantity of water which would strike a unit of surface in a unit of time. For example, in Fig. 1 a unit of surface one foot from a point-source of light of one candlepower has a flux-density or intensity of illumination of one foot-candle. Two feet from the source of

FIG. 2.



Principle of the photometer.

light, the surface over which the same flux of light is spread is four times as great, and the average flux-density is therefore only one-fourth of one foot-candle. We may, therefore, write the formula which is used as the basis of one method of calculating illumination

$$I = \frac{CP}{d^2}$$

where I is the flux-density in foot-candles, $C\ P$ is the intensity of light in candlepower and d is the distance in feet from the light-source to the point considered. Although rarely appreciated, the fact must not be over-looked that the candlepower, foot-candle, and lumen are essentially rates, and hence involve in themselves the element of time. For example, the lumen is defined as the quantity of light passing a unit area in one unit of time. Rates cannot be bought and sold but quantities can. Lumens, or that which is used to produce them—kilowatts, —cannot be bought and sold but lumen-hours or kilowatt hours can be.

In deducing the equation given above, we have considered light striking a surface perpendicularly. When the surface is inclined to the direction of light, a given flux is spread over a larger area as illustrated in Fig. 3. The flux-density or illumina-

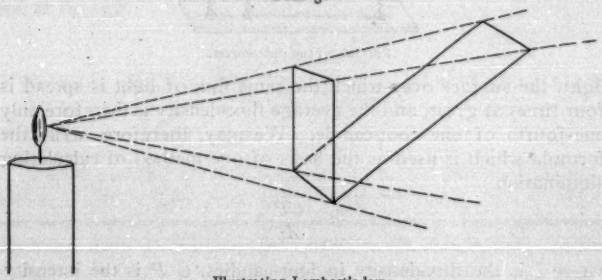
tion is therefore decreased and this decrease is proportional to the cosine of the angle. This is known as Lambert's law, and introducing it into the formula, we have

$$I_h = \frac{CP \cos \theta}{d^2}$$

where I_h is intensity of illumination on a horizontal plane as distinguished from a plane normal to the direction of the light rays, and θ is the angle which the ray of light makes with a line perpendicular to the horizontal plane.

This is the formula used for determining the flux-density or intensity of illumination in foot-candles at any point on a horizontal plane. The formula with θ equal to 0, forms the basis

FIG. 3.



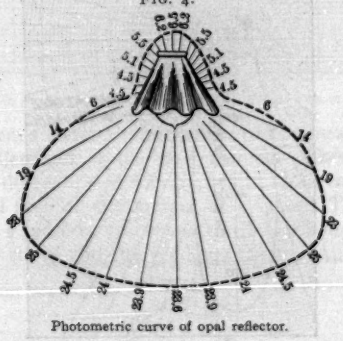
Illustrating Lambert's law.

of the photometer or instrument for measuring light intensity. The measurement is accomplished by balancing the illumination from the light-source being measured, against the illumination obtained from a standard light-source and then introducing into the equation the squares of the distances from each light-source to the comparison screen. This principle is illustrated in Fig. 2 and forms the basis of practically all photometers, although the more elaborate instruments are complicated by various devices for obtaining precision and ease of operation. By means of the photometer we can obtain the candlepower or intensity of light of a light-source in any direction.

Fig. 4 shows a photometric curve. This curve is found by a photometer and shows the candlepower of light in all directions,

in a vertical plane, from directly underneath the light-source to the point directly above the light-source. In obtaining these values, the lamp and reflector were considered as a single point of light and since the comparison screen was at a distance of 10 feet from the lamp and reflector, the assumption of a single point introduces but little error. Fortunately, the intensity of light of most of our light-sources is the same in any direction in any particular horizontal plane. The distribution in a vertical plane, therefore, shows the intensity in every direction. Very slight errors are eliminated by making this a test in the mean vertical plane. To obtain these mean values, the light-source is rotated

FIG. 4.



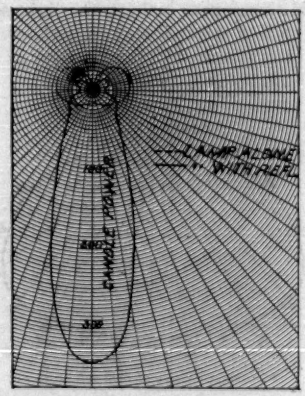
Photometric curve of opal reflector.

about its axis during testing at such a speed that each candlepower reading is the average reading for the horizontal plane in which it is taken.

As a representation of the quantity of light emitted from a source, the photometric curve is exceedingly deceptive. The natural tendency in considering a curve of any kind is to regard the area as a representation of quantity. In Fig. 5 at first sight it would appear that the curve of the lamp and reflector shows a greater amount of light than the curve of the bare lamp. This is not true; the candlepower of the lamp and the total quantity of light are practically the same in both tests. The area of a photometric curve is meaningless. The reason is that the candlepower at the horizontal represents the intensity of light through-

out a larger zone than the candlepower at the vertical. The zones throughout which the light is distributed might be compared to the zones on the surface of the earth. Consider for a moment a hollow transparent sphere with a light-source at the centre and zones similar to those on the earth laid out on the surface of the sphere. Take two zones of equal width, one near the equator and one near the poles. It is apparent at once that the zone near the equator is of greater area than that near the poles and since the photometric curve shows the candlepower in a vertical plane,

FIG. 5.

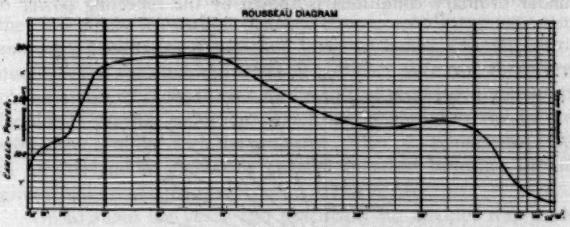


60 watt, 48 c. p. bowl-frosted Tungsten lamp with Holophane reflector, No. 9651.

candlepower values near the horizontal represent more light than equal values near the vertical. It follows that an average of candlepower values taken at equal intervals on the curve is not the average candlepower of the light-source. To obtain this true average or mean value, the curve can be plotted on what is known as the Rousseau diagram. This is illustrated in Fig. 6. The angles are laid off at distances proportional to the areas of corresponding zones on a sphere. The curve may be plotted on this diagram and readings then taken at equal intervals. The average of these readings represents the true average or mean candlepower in the upper or lower hemisphere or both as the case may be.

Recently a shorter method of determining this has been introduced and is represented in Fig. 8. In each hemisphere ten lines are shown, and if candlepower readings are taken from the photometric curve at each of these ten angles, and their sum divided by ten (in other words, the average taken) the result will be the

FIG. 6.



Curve of D. C. 3¼ amp. arc lamp, with opal inner and clear outer globes.

mean lower hemispherical candlepower or the mean upper hemispherical candlepower as the case may be. These lines are so spaced on the diagram that they represent mean candlepowers of zones of equal area on the surface of a sphere. The angles may be laid off on a piece of transparent celluloid which can then be placed on any curve and the readings taken. An advantage of

FIG. 7.

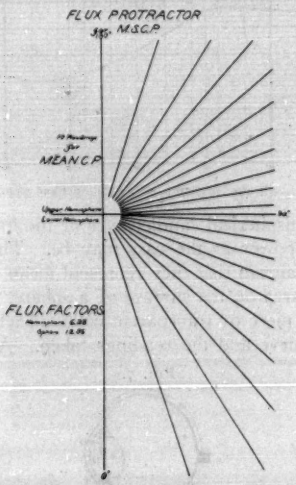
Section of the eye

this method is that it enables one to obtain mean values in other zones by properly laying off the angles. For example the mean candlepower in the zone from 0 to 60 degrees can be obtained by means of a piece of celluloid with ten lines properly spaced for taking ten readings in this zone. The advantage of the ten readings is that in taking the average of the readings, ten is the easiest number to divide by.

In order to give some idea of the reason why the science of illuminating engineering has grown so rapidly it is necessary to realize what immense improvement can be obtained by properly

calculating the lighting system of a room. The photometric curve of a bare lamp shows that practically the same amount of light passes above the horizontal as below. The light which passes above the horizontal is useful only in illuminating the ceiling and for illuminating the lower part of the room by being reflected downward. The quantity of this light which is reflected under ordinary conditions is shown by the reflecting power of

FIG. 8.



Protractor for obtaining mean candle power readings.

various colors. For instance, according to Bell,[1] ordinary white foolscap paper reflects about 70 per cent. of the light striking it; orange paper reflects about 50 per cent.; yellow paper reflects 40 per cent.; pink paper 36 per cent.; light blue 25 per cent.; emerald green 18 per cent.; bluish green 12 per cent.; ultramarine blue only about 4 per cent. In addition to this, when it is considered that the light rays which pass upward are ordinarily reflected two or three times before reaching the lower part of the room, causing

[1] Standard Handbook for Electrical Engineers (McGraw Pub. Co.), p. 745.

this coefficient of reflection to enter as the second or third power, it becomes evident that the light which passes upward is very largely wasted. Recent tests[2] on the effect of light and dark walls, ceiling and floor show that under conditions by no means extreme either way, a difference of about 4½ to 1 can be obtained in the illumination resulting from the same lamp. In addition, when the efficiency of incandescent lamps is considered, we have the choice between carbon filament lamps in ordinary use, consuming 3.5 watts per candle, and tungsten lamps, recently introduced, which consume 1¼ watts per candle. We can, therefore, obtain a difference of 13 to 1 in the cost of securing illumination by simply varying conditions which might appear trivial to one who is not familiar with the problem. This is a remarkable state of affairs, and is without a parallel in other branches of engineering.

Up to about ten years ago practically no attempt was made in designing a lighting system, to obtain uniform illumination of any desired intensity. In electric lighting certain rules as to watts per square foot or watts per cubic foot were applied indiscriminately, paying little attention to the color of the walls, to the character of the room, the position of the lights or the absorption and distribution of light by the globes and reflectors used. After the wattage had been determined the lights were spaced largely by guess-work or with the idea of obtaining the best appearance with regard to the details which the architect wished to bring out. The first method of calculating illumination was called the point-by-point method, and consisted in assuming a certain lighting system, then finding the illumination at typical points in the room by means of the formula stated in the first part of this paper. Then if the lighting system was not good as shown by these calculations, it was changed and the calculations repeated. This was a rather laborious procedure, but the few men who used such calculations soon became experienced enough to design a lighting system with little actual figuring, and they used the point-by-point method largely for checking.

Recently, however, a much shorter method of calculation called the flux method has been introduced. Its development is

[2] "Some Experiments on Reflection from Ceiling, Walls, and Floor"—V. R. Lansingh and T. W. Rolph, in the Transactions of the Illuminating Engineering Society, vol. iii, p. 584, Oct., 1908.

largely due to the work of Messrs. Cravath and Lansingh.[3] By this method the flux or quantity of light emitted from the light-source in useful directions is used as a basis rather than the candlepower or light intensity in any direction. With small light-sources the lumen or unit of quantity of light is the flux of light emitted in unit solid angle by a light having an intensity of one candlepower in all directions. It so happens that this quantity of light divided by the area of the surface which it strikes gives the average foot-candle intensity of illumination on this surface. This can be briefly shown as follows. Consider a sphere of radius r with a light-source of average candlepower P.

From the law of inverse squares—

Average foot-candles on the surface of the sphere $= \frac{P}{r^2}$. The area, A, of the sphere is $4\pi r^2$; hence $r^2 = \frac{A}{4\pi}$.

There are 4π unit solid angles in any sphere; hence the lumens generated $= 4\pi P$.

$$P = \frac{\text{Lumens generated}}{4\pi}$$

$$\therefore \text{ average foot-candles} = \frac{\text{lumens generated} \times 4\pi}{4\pi \times A}$$

$$= \frac{\text{Lumens}}{\text{Area}}$$

This applies for a plane or any other surface as well as a sphere, so that the average foot-candle intensity on any surface may be found by dividing the flux striking that surface by the area of the surface. This is a very convenient fact and enables us to obtain the average foot-candle intensity in a room by simply knowing the total number of effective lumens and the area of the room. By effective lumens is meant the total quantity of light striking the plane of illumination or, in other words, the total light generated minus that absorbed by the ceiling, walls, floor, and lighting accessories. The total number of effective lumens must be based upon some estimate as to what proportion of the light is effective, but we can work within a small limit of error

[3] "The Calculation of Illumination by the Flux of Light Method"—J. R. Cravath and V. R. Lansingh, Transactions of the Illuminating Engineering Society, vol. iii, p. 518, October, 1908.

when we know the photometric curve of the light unit and the conditions of the ceiling and walls. For example, with light ceiling and dark walls and prismatic intensive reflectors we know that the effective light is the equivalent of the light emitted from the light unit, up to about 75 degrees from the vertical. We can find from the photometric curve by the method previously explained the number of lumens produced by the light-source in this zone. The total lumens necessary is the product of the intensity of illumination desired and the area of the room. Knowing the lumens necessary and the effective lumens from each light-source, it is an easy matter to determine the number of light-sources required. These light-sources must then be placed in such a way that the illumination will be uniform, but this placement is not difficult for one who is familiar with photometric curves.

A short way of applying this method of calculation consists in using certain constants, which have been determined by illumination tests. These constants show the lumens per watt or foot-candles per watt per square foot obtained under various conditions, such as different colors of the walls and ceilings, different kinds of reflectors and globes, and different kinds of lamps.

The formula for using these constants is as follows:

$$\text{Total watts necessary} = \frac{\text{foot-candles desired} \times \text{area of room}}{\text{lumens per watt}}$$

The constants given below apply for a medium-sized or large room with light ceiling and lamps 8 to 15 feet above the plane of illumination.

Lamps	Equipment	Walls	Constant lumen per watt
Tungsten at 1.25 w.p.c.	Clear prismatic reflectors	Light	5.0
Tungsten at 1.25 w.p.c.	Clear prismatic reflectors	Dark	4.0
Tungsten at 1.25 w.p.c.	Enam. or etched prismatic reflectors	Light	4.3
Tungsten at 1.25 w.p.c.	Enam. or etched prismatic reflectors	Dark	3.4
Gem at 2.5 w.p.c.	Clear prismatic reflectors	Light	2.2
Gem at 2.5 w.p.c.	Clear prismatic reflectors	Dark	1.8
Carbon at 3.1 w.p.c.	Clear prismatic reflectors	Light	1.8
Carbon at 3.1 w.p.c.	Clear prismatic reflectors	Dark	1.5
Carbon at 3.1 w.p.c.	Lamps bare	Light	.60 to 1.3
Carbon at 3.1 w.p.c.	Lamps bare	Dark	.5 to .8
Carbon at 3.1 w.p.c.	Opal dome or cone reflectors	Light	1.7
Carbon at 3.1 w.p.c.	Opal dome or cone reflectors	Dark	1.4
5 amp. D.C. Arc	Clear inner and opal outer globes		2.0

This method may be applied equally well for gas calculations in which case the formula would read:

$$\text{Cu. ft. of gas per h. necessary} = \frac{\text{foot-candles desired} \times \text{area of room}}{\text{constant}}$$

The constant would be lumens per cubic feet of gas per hour necessary to produce one foot-candle. Very few reliable illumination tests have been made on gas equipment, however, so that the method cannot be widely applied. Mr. Norman Macbeth [4] has determined the lumens per cubic foot of gas per hour for a large room with light ceiling, dark walls and inverted gas burners with prismatic reflectors. The value is 104. After the total watts or total cubic feet of gas per hour necessary have been determined they must be divided up among the number of units desired, spaced in the proper manner. This method of calculating illumination promises to prove exceedingly valuable. At the present time we lack constants for many conditions commonly met with. As fast as reliable illumination tests are made, however, constants can be added to the list and the scope of the table increased.

A paper of this kind is not complete without some consideration of various methods of equipping light-sources. Such equipment may be divided into three general classes; globes, reflectors, and shades. Globes are enclosing or partly enclosing accessories, which may or may not have a favorable effect upon the distribution of light obtained from the light-source. Reflectors are accessories which change the distribution of light by means of reflection. Shades, as their name implies, are accessories which have as an object the decreasing of the light intensity or the addition of some decorative effect desired. As a rule they do not have a favorable effect upon the distribution of light.

There are several kinds of enclosing globes in ordinary use. The principal ones of these are prismatic, opal, ground glass, and art glass. Neglecting the question of appearance, prismatic globes are superior to opal or ground glass, since their absorption is considerably less and they are designed to direct a large part of the light rays into a useful direction. Prismatic globes such

[4] "The Illumination of an Auction Room"—Norman Macbeth, The Illuminating Engineer, November, 1908, p. 488.

as holophane, when designed and used correctly, absorb from 10 to 14 per cent. of the light. Tests on incorrectly designed prismatic globes have shown an absorption as high as 34 per cent. Opal absorbs from 25 to 60 per cent., depending upon the density. In order to obtain a desirable appearance opal globes should never be used unless they are sufficiently dense to hide the outline of the lamp filament. Ground glass absorbs from 20 to 40 per cent. Art glass has a very high absorption, but is valuable in obtaining decorative effects.

There are a large variety of reflectors on the market, among which the most common are prismatic, opal, mirror, metallic, and coated. Reflection from any surface is of two kinds—regular or specular reflection and diffuse reflection. When a ray of light is regularly reflected the angle of incidence is equal to the angle of reflection. With diffuse reflection the light striking the surface is broken up into a large number of rays which leave the surface in all directions. Most surfaces give both regular and diffuse reflection with one kind predominant. Each kind of reflection has its advantage for certain cases. Certain types of distribution of light can be obtained only with surfaces giving specular reflection. On the other hand specular reflection with filament lamps often produces bright streaks or striations in the illumination of a surface. These can be eliminated by using frosted lamps and in some cases by using bowl-frosted lamps. Completely frosted lamps are usually undesirable because frosting reduces the life of the lamp about 50 per cent. Where the reflection is diffuse, striations are not usually met with.

With prismatic reflectors, it is impossible to direct all the light rays downward. This quality is not objectionable, however, for general illumination, since it is desirable to have a certain amount of the light pass upward in order that the ceiling and upper walls may not be in darkness. Prismatic reflection is specular reflection; it is, therefore, possible to direct a light ray in any direction and a prismatic reflector can be constructed to give practically any desired distribution of light. Mirror reflectors differ from prismatic reflectors in that they allow no light to pass upward. Reflection here is specular also, and, therefore, such reflectors can be designed to give nearly any desired distribution. The fact that they allow no light to pass upward makes them objectionable for general illumination, although a system

of indirect illumination [5] recently introduced makes use of mirror reflectors. Opal reflectors are as a rule fairly efficient, but they differ from prismatic and mirror reflectors in that the reflection obtained is diffuse and not specular. This means that only photometric curves of a general rounded shape can be obtained. Opal reflectors having a depolished interior surface have recently been introduced. The depolished surface practically eliminates striations in the illumination obtained. These reflectors present an attractive appearance and have a good efficiency when used with clear lamps. Tests with bowl-frosted lamps are not yet available. Metal reflectors can be obtained in a large variety of styles and sizes. Their principal use is for factory lighting, although iron reflectors with a coating of white enamel are used considerably for street lighting. Reflectors for factory lighting are usually of aluminum, brass or steel. With such reflectors a diffuse reflection is highly desirable. This is usually obtained by a depolished aluminum surface or by aluminum paint.

Illuminating engineering covers so broad a field that this paper can do no more than touch a few of the essential features. Although the work of the illuminating engineer is comparatively new, it has proved so valuable that the development of the science and art has been exceedingly rapid. The literature on the subject has already assumed large proportions and each year sees additions of great value. The growth of the Illuminating Engineering Society is an evidence of the prevailing interest in the subject. Formed three years ago it has grown faster than any other engineering society in existence and now numbers over 1000 members. The papers presented before its meetings contain some of the most valuable data available on the subject. There is much work yet to be done before illuminating engineering is fully recognized as an important factor by all parties concerned, but at the present rate of advancement this complete recognition is not far off.

[5] "Indirect Illumination"—Augustus D. Curtis and A. J. Morgan, Transactions of Illuminating Engineering Society, vol. iii, p. 740, Dec., 1908.

MINING & METALLURGICAL SECTION

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ALLOY STEELS FOR MOTOR-CAR CONSTRUCTION.

BY

JOHN A. MATHEWS, Ph.D., Sc.D.

At the beginning of the twentieth century there was no automobile industry; to-day, before one decade has passed, we see a new industry of imposing magnitude. There are in the United States over two hundred and fifty makers of automobiles, and this number does not include makers of commercial motor vehicles and trucks. In short, it refers to makers of cars primarily for pleasure purposes. Upward of one hundred thousand employés are directly engaged in these factories and not less than four thousand allied industries and works are more or less dependent upon the motor-car industry. Truly this is remarkable growth and if, by reason of its years, this is still an "infant industry," all must admit that it looks like a thriving infant.

The value of sales of cars of domestic manufacture during the past six years is approximately two hundred and fifty millions of dollars, while over fifty millions have been spent upon foreign made cars.

As regards the productive cost of automobiles, both foreign and domestic, it appears that about 30 per cent. of the expense goes for wages and 60 per cent. for materials of construction. The remaining 10 per cent. represents salaries and materials for plants. Since 60 per cent. of the entire expense of manufacturing cars represents materials, no apology need be offered for presenting a paper before this Institute upon the *kind* of materials best suited for the construction of the vital parts. In this paper we propose to consider certain economic phases of the subject together with some matters of shop expediency and the relation of various manufacturing methods to the *quality* of the finished parts. We use the term "vital parts" advisedly because upon the quality of materials used in certain parts, the safety and even the life of the automobilist depends.

The exigencies of the demands of motor-car construction have proven a wonderful stimulus to the metallurgy of special steels. The heavy moral responsibility which rests upon both the maker and user of alloy steels and the tremendous duty expected of these materials of construction,—lightness without sacrifice of toughness or strength,—tend to make the requirements of the automobile trade most exacting.

While a few makers of automobiles and still fewer makers of steel accept this view and realize their grave responsibility, by far the majority of them seem lacking in this conception of their duty. With the steel maker it is too frequently a question of great tonnage only, and with the customer it is a question of buying at the lowest price, without due consideration of what the consequences of using cheap and inferior materials may be.

There are any number of steel makers who can display choice samples of their wares; the number of those who can furnish the same thing twice on order is much smaller. It is the ability to deliver the same article twice that makes for success in the manufacture of alloy or tool steel.

During the recent commercial depression the automobile industry thrived while the steel industry languished. A ruinous competition has been waged in the alloy steel business and these products have, in general, been sold at absurdly low prices, wholly inconsistent with that consideration of quality which motor-car construction deserves. This has retarded progress in the development of new steels.

It is inconceivable to my mind how any firm can conscientiously put out a car and not know intimately the materials used in every essential part. Yet such is frequently the case—gears are bought from "A" solely because his price is lower than that of "B" and "C," but the materials from which they are made are often unknown to the purchaser and rarely specified excepting perhaps in a general way. For example, nickel steel is asked for. Now nickel steel is a delightfully variable and uncertain quantity as ordinarily made. To say that you use nickel steel is about as definite as to say that you own an automobile—it may be a Packard limousine or a farmer's high-wheel auto-buggy. Both run by their own power on four wheels, but there the resemblance ceases. There are of nickel steels—like pickles—at least fifty-seven varieties, and the user should know what *kind*

of nickel steel goes into his gears and who makes the steel as well as the gears.

Dr. Guillet, the distinguished French metallurgist, has previously pointed out that the constitution and mechanical properties of nickel steel depend essentially upon the sum C + Ni. From my own experience I should add to this sum + Mn. One hears continually in the trade nickel steel referred to solely by its percentage of nickel. Such expressions possess no real significance as a measure of quality or adaptability for various purposes. It is the skilful blending of the elements C + Ni + Mn that counts, and the successful accomplishment of this is a fine art. Almost as bad as not specifying at all is the tendency upon the part of many buyers to tell the maker how he ought to make his steel; to specify chemical analysis and physical tests which are a misfit, and, to quote Dr. C. B. Dudley, to make the wording of the specification "a place to show how much they know, as well as [to display] a mental attitude of favor or antagonism to any of the parties affected by it." I wish we might consider somewhat fully the subject of specifications, but for want of time I can only refer to Dr. Dudley's Presidential address to the American Society for Testing Materials, in July, 1903. It would be useless for me to attempt to add anything to what Dr. Dudley has so well said. Permit me, however, in passing to quote a few of his words:

"A specification for material should contain the fewest possible restrictions, consistent with obtaining the material desired. The service which the material is to perform, in connection with reasonably feasible possibilities in its manufacture, should determine the limitations of a specification. All parties whose interests are affected by a specification should have a voice in its preparation. Excessively severe limitations in a specification are suicidal. They lead to constant demands for concessions, which must be made if work is to be kept going, or to more or less successful efforts at evasion. Better a few moderate requirements rigidly enforced, than a mass of excessive limitations which are difficult of enforcement, and which lead to constant friction and sometimes to deception."

In these few words Dr. Dudley has spoken volumes and his entire address, "The Making of Specifications for Materials," will repay earnest study.

In my address this evening it is not my intention to weary you with long tables of analyses and physical tests. Perhaps a few will be mentioned incidentally and more added in an appendix. What I especially desire to emphasize are certain economic features in connection with the manufacture, purchase, use, and treatment of alloy steels of various types. Not all parts of an automobile demand especially high-grade material, while some parts demand the best of alloy steels. Indeed their use might well be made compulsory in the interest of public safety. We have seen manufacturers err in using too good materials in unessential parts, but the opposite tendency is more general.

Sound business judgment demands the best materials in vital parts, first, because of increased safety; second, because of the reduction in the guarantee cost, and third and most important, because of the advertising value of a clean score on breakage for a whole season's output. Dynamically strong axles, tough and strong steering parts, and springs which neither sag nor break are essential to comfort and safety. The crankshaft ought to be stiff and strong, the valve mechanism must resist wear, and the valve springs must retain their resilience indefinitely. Connecting rods, cap screws, clutch springs, gears and shafts, all moving and sliding parts of the transmission, bevel driving pinions and driving shafts, truss rods and torsion bars, all have more or less severe duty to perform and require materials possessing in various degrees resilience, strength, toughness, wearing qualities, and anti-fatigue qualities of high order. To make these parts of cheap and inferior stuff is not a good business proposition. The failure of such parts injures the reputation and name of any car and it is well to remember that contented owners of cars are their best advertisers.

As a manufacturer endeavoring to produce at all times the best qualities of tool and alloy steels, I see and hear much of that class of buyers to whom price is the all-important consideration. The ability, honesty, and reputation of the steel-maker carries no weight with them. A quarter of a cent difference in price far outweighs any considerations as to the relative knowledge, experience or facilities of competing makers. You can't get something for nothing and if you get something for next to nothing it is likely to cost you dear in the end. Let us consider what it means, for example, to buy a satisfactory steel for gears—

one which will produce gears that will never break—and a mediocre steel costing three-fourths as much from which some trouble is inevitable. A fair cost for a transmission, complete, would be perhaps eighty dollars; of this amount the steel for the gears themselves might cost ten or seven and one-half dollars, or one-half or three-eighths of one per cent. respectively of the $2000 car. By using the better steel you have increased the cost of your complete transmission a little more than three per cent. and the cost of the car by one-eighth of one per cent. This minute increase might readily represent the difference in cost involved and the results attained might well be considered very cheap advertising. Very few automobile makers are manufacturing on such a close margin of profit that they can afford to risk failure through false economy. The difference between a good and a poor steel of any particular class rarely exceeds two cents per pound. If the design is right and parts not needlessly heavy and if proper discrimination is shown in the selection of the right steels for various parts, the difference in raw material cost will amount to but a small percentage increase in the final cost and as an investment will be better than Standard Oil stock at par. The product is vastly improved; the car is safe and reliable; it advertises and sells itself.

I hope you will pardon me, if I digress for a few moments and tell you something of the steel company which I have the honor to serve as manager. We have good reason to take pride in our mill and equipment, and if any of you have ever visited our works I am sure you will confirm me in this. In general new steel mills are given considerable attention by the technical press and full descriptions are published with illustrations. Suffering from excessive modesty or other cause, very little has been given to the press about our plant. The Halcomb Steel Company is not even as old as the automobile industry. It is new in one sense only, however, it is a newly incorporated company with a new plant. Within five years it has erected the largest steel works in the United States devoted exclusively to the manufacture of high-grade tool and alloy steels. Competent authorities tell us we have the best arranged mill and equipment in the world for our class of work. That may seem a strong statement but I am quoting the opinions of English and American steel men and not my own. When the Lusitania made her maiden

trip she was not manned with longshoremen. No, the best men in the employ of the Cunard Company were promoted; experienced men only were wanted. So in our plant, modern from stem to stern, we have an old mill organization of proven ability that has weathered many storms. Our working organization of department superintendents and foremen, intact almost to a man, has been associated for upward of twenty years in the manufacture of tool steel. Their fathers and grandfathers were steel men and their sons are following in the same occupation. Sheffield hasn't a monopoly upon ancestry in the tool-steel trade. We have men of the fifth and sixth consecutive generations of steel-makers with us and we cling tenaciously to the best methods and traditions of Sheffield tool-steel practice as regards the crucible process. We also have the first commercial electric steel-melting furnace erected on the Western Hemisphere. For three years the Heroult electric process has been used in our works. We thus combine conservatism and progress in our selection of methods of steel-making.

When we took up the manufacture of alloys for automobile construction we engaged as metallurgical engineer a man experienced in automobile engineering, a man familiar with specifications, testing and heat treatments, the design and construction of cars, and familiar with the troubles that have been encountered by the automobile manufacturers. In making these new alloys we want more knowledge of them than a chemical analysis and a tensile test. We consider the proposition in its entirety, including machining qualities and corresponding productive costs in the user's shop.

We manufacture many types of alloy steel but, of course, have our preferences. Upon request we can furnish expert advice in reference to the choice of materials for various parts and are pleased to co-operate fully with those desiring the best material in every part. By studying individual constructions, the expense of needlessly good material in unimportant parts is prevented while just the right thing for essential parts will be recommended.

No alloy steel is a universal steel. They must be selected with fine discrimination, giving due thought to the duties they must perform. Obviously the careful maker should be more intimately acquainted with his products than the user can be, both as regards chemical and physical qualities and thermal treatment and, hence,

we willingly place our years of scientific and practical experience with alloys at the service of users of these products.

Quality rather than tonnage is our first desire. Each product must be the best of its kind; it must be uniform, year in and year out; it must be physically sound, free from pipes and seams and pass rigid inspection. In short our alloy steels are handled with all the care and minute attention to details affecting quality that characterizes our finest tool steels. This way of doing business costs money. When I mentioned a few moments ago paying a few cents a pound more for a good steel, that is just what I meant. I did not mean that one should pay ten cents for a seven cent steel. That won't improve the quality of the steel. I maintain that purchasing a steel *worth* ten cents is in nine cases out of ten economy over a steel *worth* seven cents, for use in vital parts.

Without attempting any scientific classification of alloy steels, or enumerating all types that have been used at home and abroad, I will briefly describe the principal types used in the American trade.

Nickel steel is perhaps the most generally used of the alloy steels. Its merits are often obscured by irresponsible makers whose product lacks uniformity—we have even heard of the nickel itself being omitted. The analysis usually desired but not always attained is, carbon .20–.25, nickel 3.50, manganese .60–.90, sulphur and phosphorus not over .04. With carbon and nickel as above stated manganese ought never to exceed the limits mentioned. A slightly lower carbon is sometimes used for case-hardening purposes, and a higher carbon is much used for crank-shafts. With higher carbon we should prefer lower manganese. A small quantity of 5 per cent. nickel steel is used in about the same carbons. Certain firms claim to sell crucible nickel steels in these compositions; personally, I have never known of a pound of such steel being made commercially, and the prevailing price of nickel steel is pretty substantial evidence that it has not been produced by the crucible process. It is usually made in the basic open hearth furnace; with reasonable care, however, nickel steel can be made uniform, physically sound, and free cutting It has remarkably good mechanical qualities when subjected to suitable heat-treatment and is an excellent steel for case-hardening. In machining qualities it usually takes first place among the alloy

steels. When extraordinary care is used in its manufacture, and it is not made in too large heats or ingots, and when piping and segregating is avoided by confining the finished product to that produced from the bottom two-thirds of the ingot, we have an admirable product for many purposes. In manufacturing such steel in the electric furnace, only relatively small ingots are made wherein segregation and piping are negligible.

Chrome vanadium steels in a profusion of types have of late attracted the profound attention of automobile engineers. Mr. J. Kent Smith has but recently discussed these products before this Institute, and his work in connection with these steels is deserving of the highest praise. As an illustration of the novelty of vanadium steel as a commercial commodity, I well recall being quoted $75.00 per pound for vanadium not many years ago.

The chrome-vanadium alloys are preferably made in the crucible or electric furnace, although the open-hearth process is also much used for the purpose. The open-hearth product, I believe, is somewhat uncertain and while, for example, an open-hearth chrome-vanadium spring-steel may be better than plain carbon crucible spring, it is not to be compared with genuine crucible chrome-vanadium steel when properly melted. For excellent quality, this product constitutes the highest attainment of the steel-maker's art.

These alloys are, in general, made in a high carbon type, suitable for oil-hardened gears and springs, and in several low carbon types,—such as a case-hardening type for gears and a type suitable for oil quenching followed by annealing for axles, shafts, and steering knuckles. By judicious blending of chromium and vanadium and adjustment of the manganese and carbon one can not only obtain all static properties that can be obtained from nickel, chrome-nickel, or silico-manganese alloys, but in addition obtain dynamic or antifatigue qualities far in excess of those displayed by any other alloys. A concrete example in confirmation of this will be given later.

From a wide experience with all types of alloys, it is my opinion that where a better material than the best nickel steel is needed, and especially when dynamic excellence is sought, the appropriate types of vanadium-chrome steels may be unreservedly commended. They forge well and machine more readily than chrome-nickels of corresponding carbon percentages.

Chrome-nickel steels are usually made in a high- and a low-carbon type. The former is used for oil-hardened gears and springs and the latter for general structural purposes, such as axles, shafts, forged parts and for case-hardened gears. The high-carbon type carries about one-half per cent. of carbon and the low-carbon alloy one-quarter of one per cent.; the nickel as supplied by various makers varies from two to three and a half per cent., while chromium from one to one and a half per cent. is usual. A nickel-chrome-tungsten steel is sometimes used for springs.

In general, nickel-chrome steels possess excellent static qualities but the difficulties in heat-treatment, forging, and machining lead one to prefer the other type of alloys previously mentioned. Equally good physical characteristics can be obtained more cheaply in first cost and in shop costs from nickel or chrome vanadium alloys. We shall speak further of the relative merits of these steels for oil-hardened gears and springs later.

Silico-manganese and silico-chrome in medium carbons have had considerable popularity abroad for springs and for gears. They, also, are made in low carbons. Their relatively low cost favors their use, but their feeble resistance to shock and sensitiveness to heat-treatment limits their use. When handled with great care they give good results in works well equipped for obtaining accurate results in their heating operations.

Chrome steels in high carbons are much used for balls and ball races.

Tungsten steels of special analysis are universally used for making magneto magnets. All statements and opinions to the contrary notwithstanding the magnet steel now made at two works in this country is rarely equalled in quality and never equalled in uniformity by foreign products. If foreign magnetos are superior to domestic ones it is because of their mechanical construction and not because they possess, in general, better magnets. The writer feels very deeply upon this subject and has probably made the most exhaustive experiments ever made upon the manufacture and properties of permanent magnet steel.

Having briefly described the type of alloys in general use we beg to submit some observations upon heat-treatments, upon the merits of case-hardened vs. oil-hardened gears; drop-forged gears vs. gears cut from the bar, and, in conclusion, a few words on springs.

Heat-treatment.—The best alloys are none too good for automobile construction; when one has secured the best the market affords, the first step only has been taken to produce good parts. Next come the forging and machining and the heat-treatment, for better or worse. It is money wasted to buy good alloys unless one is willing to study them sufficiently to know how to treat them and then to supply adequate facilities for so doing.

It is not to be expected that small users will install complete testing laboratories, but a few dollars invested in having occasional tests made will be well spent. There are, however, many large concerns that could and should spend, say $5000, for which it is believed the whole or a large part of the following equipment could be obtained: The ordinary tensile machine, a microscope, electrical or gas furnaces capable of fine regulation, a good pyrometer, preferably recording. The tensile machine can also be used for making Brinnell hardness tests, spring deflection tests, etc. In addition to these some form of drop-testing machine, such as the Fremont, will be found valuable; a vibratory or repetitive impact test is nowadays considered a necessity, while cold bending and torsion apparatus is useful. This equipment will be of small use, unless a thoroughly good man is put in charge—a careful, conscientious man of sound judgment. This man should direct the heating operations in the factory; he should construct furnaces which heat uniformly, and he should exercise eternal vigilance in keeping the pyrometer installations up to par.

The pyrometer is too often supposed to take care of itself. Too frequently it is never questioned, never calibrated. The best pyrometer of the thermocouple type should be looked over at stated intervals, especially if in constant use. Protecting tubes should be frequently examined and renewed, and electrical contacts looked over. Occasionally check up the millivoltmeter. Unfortunately there are many pyrometers of the thermocouple type on the market which cannot be watched too closely.

If you are going to have pyrometers, by all means see that you have good ones and then see that they are systematically tested. Many people buy high-priced alloy steels and get no better results from them than could be had from a carbon steel properly handled. If you cannot afford a good pyrometer stick

to the trained eye of a skilled man; and if you have a good pyrometer employ a skilled man anyway, and consider the pyrometer as an aid. With it you can at least give orders in temperatures rather than in heat colors, and the laboratory and works can meet on an intelligent basis.

Heat-treatment operations depend upon a solid scientific basis. By this we do not mean that steel essentially of inferior quality should be made to pass muster by heat-treatment. On the other hand, however, it might be said that alloy steel in its so-called natural state, as it comes from the rolls, hammer or drop-forge, is almost unfit for automobile construction. Steel which depends upon alloys for a high elastic limit in its natural condition will have much less elongation than the same steel oil-tempered and annealed. For example, a chrome steel gave in its rolled condition 158,000 pounds elastic limit and 5 per cent. elongation, with 9.4 per cent. reduction of area. The same steel oil-tempered and annealed gave 153,000 pounds elastic limit, 14 per cent. elongation, and 52 per cent. reduction of area. In other words, the material was transformed from brittle to tough, from treacherous to safe, without materially affecting its elastic limit. A nickel steel similarly treated had its elastic limit raised 20 per cent. with the reduction of area improved and its elongation unchanged.

Case-hardened vs. Oil-hardened Gears.—In the automobile trade there have existed two schools, so to speak, one believing in the case-hardened type of gear and the other in the oil-hardened type. As previously mentioned the chrome-vanadium, chrome-nickel, and silico-manganese alloys are made in both high and low carbons. The former contain about .45 to .60 per cent. carbon and enough other hardening elements so that by merely quenching in oil from a bright red heat a surface-hardening is produced sufficient for ordinary wearing purposes while the hardness does not penetrate deeply into the gear but leaves a core that is tough and strong. The low carbon alloys, with about .20 per cent. carbon, require to be carbonized or case-hardened in order to produce sufficient surface-hardening for wearing purposes after hardening. The speaker's word on the merits of gears made by these two methods will hardly be accepted as final, as he is not an authority upon gears. Several years of observation and contact with the trade, however, leads me to prefer the case-

hardened gear. The result of direct tests upon thousands of gears of both types leads me to the following conclusions: (1) The static strength of a case-hardened gear is equal to that of an oil-hardened gear, assuming in both cases that steel of the same class and appropriate analysis has been used and that the respective heat-treatments have been equally well and properly conducted. (2) Direct experiments proved that the case-hardened gear resists shock better than the oil-hardened. (3) As regards resistance to wear the same type is incomparably better, although perhaps not as silent in action.

One of the leading makers of gears has proved this to his own satisfaction of late by an arrangement of shafts and gears whereby energy is transmitted through two case-hardened gears, in mesh with each other, to two oil-hardened gears. The gears are of the same size. The conditions of the test were severe. Five sets of the oil-hardened gears have already been worn out while the original case-hardened gears are still in service and show the tool marks.

Upon the part of many there is strong objection to case-hardening. In nine cases out of ten this is doubtless due to the fact that the case-hardening operation has not been reduced to a science. The depth of case, the relation of case to core, the time and temperature to produce certain results and the exact control of these conditions, together with an accurate knowledge of the material to be treated, are the factors that enter into successful case-hardening practice. Further points in favor of this method are easier machining of the blanks, and at least equal static and dynamic properties with less chance of injury in hardening.

While considering gears, we may as well dip in a little deeper and consider the relative merits of gears cut from bars and from drop-forged blanks. Parts like spur gears, bevel pinions, and many shafts may either be drop-forged or cut from bars in automatic machines. Contrary to general opinion many parts can be machined out of bars as cheaply as they can be from forgings. Moreover, I am firmly of the opinion that no steel is improved physically by drop-forging, some steels, of course, being less susceptible to injury than others. In good steel mill practice great attention is paid to proper finishing heats, and steel is brought gradually to size. In drop-forging work, in order to give sufficient plasticity to assume various forms in dies, it must be

heated very hot. It is then frequently formed with the fewest possible blows. An investigation of drop-forged and bar-cut gears, the former being the product of one of the foremost drop-forging companies, showed that under static test the bar-cut gears, as the average of many tests, were fully 25 per cent. stronger, and their resistance to shock test was also much better, but the difference cannot be exactly stated in percentage. The fact that the static test did not show more than 25 per cent. average superiority for the cut gear was a surprise to me and speaks well for the forging concern in question. In many cases, I fear a larger difference would be found. It is just such points in the construction of various makes of cars of the same general design that would be of great benefit to the would-be purchaser could he but know them.

To show that case-hardening is a science, let me quote from Dr. Guillet once more. In reference to the proper procedure in case-hardening he says: "As is well known, the operation of case-hardening consists of placing a steel in some medium capable of imparting carbon to it, at a suitable temperature; after a sufficient interval a steel is obtained the interior of which possesses the same percentage of carbon as before case-hardening, but the exterior of which is much higher (0.80 to 1.00 per cent.). On quenching such a steel an extremely high degree of mineralogical hardness is obtained on the surface, while the centre of the piece is non-brittle, if, that is, the operation as been properly carried out. One generally uses steels containing .10 to .25 per cent. of carbon for case-hardening. In order to avoid all brittleness in the interior and exterior of the piece, and, at the same time, to obtain a high degree of superficial hardness and a very regular degree of carburization (in carbon steels) it is necessary—

1. "To use a steel containing less than 0.12 per cent. of carbon, and with a low percentage of manganese (less than 0.30 per cent.) and—

2. "To case harden with a chemically definite material such as a mixture of 60 parts charcoal and 40 parts of barium carbonate at a temperature between 850° C. and 1050° C.—the higher the temperature the more rapid the case-hardening—and allow it, after the operation, to cool down just below the transformation point (about 600° C.).

3. "To reheat the piece and quench it at 900° C. (just above

the transformation point of the centre), this operation having the effect of rendering the centre fibrous."

This operation has the effect of toughening the centre but the outside will be coarse-grained and brittle. The next operation, according to Guillet is—

4. "To quench for a second time at 800° C. (above the transformation point of the exterior), to render the skin non-brittle.

"In any case, the methods by which it is possible to obtain, with low-carbon steel, case-hardened pieces which shall not be brittle, are exceedingly delicate."

How different this is from the operation one too often sees, where the pieces are dumped directly from the case-hardening boxes into water. However, if one uses a good grade of nickel steel, low in carbon, and case-hardens at appropriate temperatures, and then takes the precaution to cool off in the boxes before heating for quenching, and then hardens at about 800° C., the results will be fully equal or better than can be obtained by the most careful handling and double quenching of carbon steels. The saving in cost of the operation can be applied toward the greater cost of nickel as compared with ordinary case-hardening steel.

Better still, however, if nickel steel is used, is to give it a double quenching, too, then one obtains a really admirable product of extraordinary toughness and remarkable wearing qualities. An ideal way of making a nickel-steel gear consists in first annealing the blank, then rough-machining approximately to size, then giving a light reannealing before taking the last finishing cut. Then pack in suitable mixture and carbonize to a depth of $^1/_{64}$ to $^1/_{32}$ of an inch, according to requirements, at a temperature of about 1625° to 1650° F. Cool in the pots, heat to about 1500° F. and quench in a hot brine or calcium chloride solution. This will put the core into excellent physical condition. Finally, reheat to 1375° to 1400° F. and quench in oil. This last operation will refine the grain of the case and harden it with best results. The temper need not be drawn.

It will be noticed that the temperatures for treating nickel steels are considerably lower than those advocated by Guillet for carbon steels.

If methods like these are followed it is not likely that a very great difference would be noted between bar-cut gears and gears

cut from drop-forged blanks. In the case of medium carbon gears not to be case-hardened but oil-hardened only, one would probably find a greater difference and in this case we have no opportunity to restore the over-heated forged blank by scientific heat-treatment. This, in addition to the greater chance of over-heating and the greater difficulty of machining, also favors the use of case-hardened gears, assuming, of course, the case-hardening is to be skilfully done.

In conclusion, let me bring to your attention certain facts and considerations with reference to springs and spring making. There are in general two kinds of springs used in automobiles, coil and flat springs. The latter may be full, three-quarter, or half elliptic. From observation and general report it appears that the general maker of springs has not kept pace with the improvements in spring-steel and with the increased severity of the duty expected of springs. With many of them to suggest a change of method is like preaching heresy in a theological school.

The new steels cannot be handled just like the old ones and still obtain from them the maximum development of their powers. However, the new steels, being in general lower in carbon, will stand much abuse in heat-treatment and still produce springs of quality undreamed of a decade ago. But how foolish it is to pay four or five times the cost of regular spring-steel and then not adopt methods to develop its maximum excellence even to an increased endurance of a hundred fold over plain carbon spring steel!

While as a class spring-makers may have been driven to the use of alloy steels, they have not as a class been forced to handle them scientifically. I am happy to say there are a few exceptions to this and I hope their number will increase. The old practice of forming and hardening springs with a single heating cannot be persisted in if maximum quality and service is to be secured.

Satisfactory tests on flat springs are somewhat difficult to make but in coiled springs quality can be easily shown and the relative merit of different steels demonstrated. The most satisfactory test is to operate the springs,—open and close,—by some sort of repetitive impact method until destroyed. In order to produce results in a reasonable length of time the duty must be

severe and the rate of alternations of stress rapid. The number of alternations of stress to produce fracture gives a measure of its vitality, so to speak. Average results of a great many tests made in this way of crucible carbon springs, chrome nickel, silico-manganese and genuine crucible chrome-vanadium springs proves the extraordinary quality of the last-named product and the antifatigue qualities imparted by vanadium. The average figures for alternations were as follows: crucible carbon spring, 125,000; chrome-nickel and silico-manganese, each 200,000; crucible chrome-vanadium, 5,000,000, and still unbroken. This, then, is the panacea for all valve, clutch, break, and flat spring troubles. The engineer of a company which makes a very heavy car and uses a semi-elliptic spring told me recently that they had not had a leaf to break or a spring to sag since adopting crucible chrome-vanadium springs made by an up-to-date spring-maker. Prior to this time they were in trouble all the time.

The tempering of this steel is quite simple. The springs should be heated to 1675° to 1700° F. and quenched in oil. The temper is then drawn according to the nature of the spring and the duty expected. The drawing range is very wide, namely, from 600° to nearly 1000° F. In the line of spring-steel this product has my profound admiration.

In what I have said this evening I have tried to impress upon you the importance of using high-class materials when severe duty is demanded, of using discrimination in the selection of special steels for special work, of looking beyond the first cost of your raw materials, and of studying the fascinating subject of heat-treatment. If I have succeeded in a measure in this, our evening will have been well spent. If I have caused any of you to think more deeply on these subjects or have made any one's conscience hurt him just a little bit because of past neglect, or have offered any practical suggestions which you can apply in your daily work to the betterment of your product, then I shall not regret having accepted the invitation to address you upon this important subject.

APPENDIX.

In presenting some tables showing typical analyses, treatments and tensile tests of nickel, nickel-vanadium, chrome-nickel, and chrome-vanadium steels, we have drawn upon many sources

of information, as, for example, the data published by the American Vanadium Company, experimental data upon tests made by the writer, and commercial tests made upon the steels of many makers. The temperatures when given are approximately correct. In giving analyses only the essential elements have been given. We have expressed the elastic limits and tensile strength in net tons per square inch, and the elongations are as measured upon a two-inch test-specimen one-half inch in diameter.

These tables are given to illustrate the tremendous possibilities of careful heat-treatments, and in some instances they illustrate the danger of applying wrong treatments. The effect of variable carbon contents in alloys of the same type is illustrated, and varying qualities that may be obtained from the same alloy by different treatments may be observed.

One point I must mention in connection with these tests is, that in designing parts one must be very cautious not to be misled by the remarkable tests yielded when a standard test-piece is treated and to use these figures as a guide to the physical qualities likely to result when a much larger mass of metal is treated. Because a half-inch test-piece oil-tempered and annealed gives an elastic limit of 75 tons per square inch, it does not follow that an inch-and-a-half-diameter bar similarly treated will yield the same elastic. The hardening action in quenching does not penetrate very deeply in a large bar, while in a small one it may penetrate to the centre.

The writer once made a quantitative experiment upon this point, using a .43 carbon steel, containing vanadium. The steel was in the form of an inch-round rolled bar. In one case I oil-tempered a full inch section of the bar at 1600° F. and annealed it at 1030° F., and from this machined up a test-piece. In the other case, I made the test-piece from the inch-round bar, and having reduced it to a half-inch diameter test-piece, subjected it to the same treatment as I had applied to the full-sized bar. The piece treated in the form of a test-piece gave me 42.5 tons elastic limit, 58 tons tensile, 21.5 per cent. elongation, and 58 per cent. reduction. The other piece was over 4 tons lower in elastic limit; over 3 tons lower in tensile, and 2.2 per cent. and 3.6 per cent. higher in elongation and reduction respectively. This shows that while it may be quite possible to obtain an elastic limit of 100

tons in a thin spring, one would not have the same elastic by the same treatment had the same steel been made into a massive gear.

Many of the figures given in the tables are the averages of several tests made upon materials of the same general kind, and in the first column of the tables is given the number of tests, either average or single, upon which the figures are based.

In the column marked "treatment" is given the temperature to which the steel has been heated, followed by the liquid in which it was quenched, and then by the temperature to which it was reheated to draw the temper or anneal. This will make clear such terms as 1600° F.—oil—600° F., etc.

TABLE 1.—NICKEL STEELS.

No. of Tests.	C.	Mn.	Ni	Cr.	V.	E. L.	T. S.	Elong. in 2".	Red. in A.	Treatment.
4	.21	.86	3.48	...	...	68	112	13.7	45	1550 F. oil 600 F.
4	.25	..	3.50	...	...	85	109	13.4	..	1550 F. oil 600 F.
2	.27	..	3.50	...	...	86	110	13.3	51	1550 F. oil 600 F.
30	.18-.28	.60-.90	3.5	...	...	68	103	12.9	54	1550 F. oil 600 F.
11	.18-.28	.60-.90	3.5	...	...	84	116	12.4	48	1600 F. brine.
4	.25	.60-.90	3.5	...	...	88	121	12.2	48	1600 F. brine.
7	.23	.61	3.54	...	...	103	114	14.0	50.7	1550 F. water 212 F.
1	.14	.63	3.64	...	...	78	88	15.0	54.6	1500 F. water 212 F.
1	.14	.63	3.64	...	...	30	41	33.5	72.4	1400 F. oil 1200 F.
4	.35	.45	3.39	...	...	77	84	15.5	55.5	1500 F. water 900 F.
4	.35	.45	3.39	...	...	130	137	10.0	36.3	1500 F. water 430 F.
3	.25	.86	3.45	...	...	31	45	31	60	Natural, as rolled.

TABLE 2.—NICKEL-VANADIUM STEELS.

No. of Tests.	C.	Mn.	Ni.	Cr.	V.	E. L.	T. S.	Elong. in 2".	Red. in A.	Treatment.
1	.34	.17	3.88	...	..	29	43	27.3	54	Natural as rolled.
1	.33	.16	3.72	...	.12	41	54	23.8	53	Natural as rolled.
1	.33	.16	3.40	...	.24	49	66	17.8	40	Natural as rolled.
1	.34	.17	3.88	...	..	37	51	16.5	51	1500 F. oil 1150 F.
1	.33	.16	3.72	...	.12	51	59	24.0	61	1500 F. oil 1150 F.
1	.33	.16	3.40	...	.24	59	62	21.0	61	1500 F. oil 1150 F.
1	.34	.17	3.88	...	..	59	66	15.5	55	1500 F. oil 600 F.
1	.33	.16	3.72	...	.12	70	76	14.5	56	1500 F. oil 600 F.
1	.33	.16	3.40	...	.24	82	85	15.0	55	1500 F. oil 600 F.
1	.24	.72	3.33	...	.12	38	49	27.0	64	Natural as rolled.
1	.24	.72	3.33	...	.12	71	100	11.6	36	1600 F. oil.
1	.24	.72	3.33	...	.12	92	117	14.5	52	1600 F. water.
1	.24	.72	3.33	...	.12	91	116	15.2	57	1600 F. brine 400 F.

TABLE 3.—CHROME-VANADIUM STEELS.

No. of Tests.	C.	Mn.	Ni.	Cr.	V.	E. L.	T. S.	Elong. in 2".	Red. in A.	Treatment.
3	.26	.39	...	.78	.17	44	68	20	64	Natural as rolled.
1	.26	.39	...	.78	.17	103	139	3	8.2	1570 F. oil 400 F.
3	.27	.50	...	1.00	.17	33	45	28	62	Annealed 1475 F.
1	.27	.50	...	1.00	.17	52	63	21	56	Oil tempered and drawn to various degrees.
1	.27	.50	...	1.00	.17	62	65	17	62	
1	.27	.50	...	1.00	.17	70	74	17	57	
1	.27	.50	...	1.00	.17	100	106	12	51	
1	.27	.50	...	1.00	.17	112	116	11	39	
1	.40	.77	...	1.22	.19	34	50	26	62	Annealed.
1	.40	.77	...	1.22	.19	98	104	10	36	1650 F. oil 840 F.
1	.30	.50	...	1.00	.16	71	76	16	56	1650 F. oil 1025 F.
3	.38	.73	...	1.19	.18	41	65	22	67	Natural as rolled.
1	.38	.73	...	1.19	.18	110	144	10.8	47	1660 F. oil 600 F.
1	.38	.73	...	1.19	.18	64	113	12.9	53	1660 F. oil 850 F.
1	.33	.54	...	1.24	.20	64	71	15.5	56	1500 F. oil 1125 F.
1	.33	.54	...	1.24	.20	95	104	11.0	38	1600 F. water 600 F.
5	.45	.58	...	2.37	.30	88	94	13.2	46	1600 F. oil 1125 F.
4	.45	.58	...	2.37	.30	138	146	6.0	16	1600 F. oil 430 F.
1	.36	.21	...	2.78	.24	60	104	4.1	88	Natural as rolled.
1	.36	.21	...	2.78	.24	65	72	20	56	1500 F. oil 1150 F.
1	.36	.21	...	2.78	.24	98	104	13	45	1500 F. oil 600 F.

TABLE 4.—CHROME-NICKEL STEELS.

No. of Tests.	C.	Mn.	Ni.	Cr.	V.	E. L.	T. S.	Elong. in 2".	Red. in A.	Treatment.
1	.37	..	2.9	1.04	...	60	78	18.5	61	1475 F. oil 1200 F.
4	.37	..	2.9	1.04	...	77	84	16.	56	1500 F. water 1100 F.
1	.45	..	2.0	1.0	...	70	90	8.0	20	Oil-temp. and annld.
1	.25	..	2.0	1.0	...	50	65	12.0	30	Oil-temp. and annld.
2	.25	..	3.0	1.5	...	57	64	15.0	65	Annealed.
1	.25	..	3.0	1.5	...	110	116	6.0	40	Hardened—oil.
1	.50	..	2.0	1.0	...	33	46	27.0	64	Natural as rolled.
3	.50	..	2.0	1.0	...	72	134	6.0	23	Tempered.
1	.30	..	2.0	1.0	...	35	53	18.0	45	Natural as rolled.
1	.30	..	2.0	1.0	...	68	98	9.0	37	Tempered.
1	.30	..	2.0	1.0	...	45	55	25.0	55	Oil-temp. and annld.
1	.40	.18	2.1	.80	...	60	76	12.8	37	Natural as rolled.
1	.40	.18	2.1	.80	...	58	66	17.5	40	1500 F. oil 1150 F.
1	.40	.18	2.1	.80	...	106	118	10.0	34	1500 F. oil 600 F.
1	.40	.18	2.1	.80	...	70	79	15.5	48	Annealed 1150 F.

ANNUAL REPORT OF THE SCHOOLS FOR THE SESSIONS OF 1908–1909

THE DRAWING SCHOOL.—The Drawing School has done excellent work this year notwithstanding the reduced attendance, due to the prevalent industrial depression. The development of the understanding and the capabilities of very many of the students has been striking, and all have been benefitted more than they are aware of. They have acquired a good conception of what graphic illustration, construction, demonstration and proof can do, and are much better prepared to take up the theoretical and academic part of engineering, structural work, architecture or original designing of any kind, than if they had begun the other way and treated the graphics as a mere adjunct. They have also slowly absorbed the idea that it is just about as easy and as quick to do things well and in good style as to do them poorly and in a slovenly manner, and that the final results of the former are far superior.

Those graduates who have selected this line of industry as their life-work, or who are so situated as to make it desirable to do so, and who believe themselves fairly capable on the graphic side, should immediately follow it up with the mathematical part, and those who do not so believe should continue at the drawing, notwithstanding their graduation, until they do.

On the part of the Institute greater effort should be made to exploit the schools. They are unique, in that the instructors are experts in their lines, and that the instruction is individual and personal and not perfunctory. The instructors may not be graduates in pedagogy, but they are skilled in what they teach, and coming into such close contact with the students, the latter absorb their methods and experience in a way that no class instruction can produce. This should be made more generally known, and the public be continually informed of the superior opportunities afforded by this Institute, with all its inadequate material facilities and its unattractive appearance and location.

WILLIAM H. THORNE, *Director.*

THE FOLLOWING STUDENTS HAVE DESERVED HONORABLE MENTION:

In the Senior Mechanical Class,

Walter Dardenne, Walter T. Sulger, William H. Weldon.
Robert J. Heisserman, James B. Stites,

In the Intermediate Mechanical Class,

Ernest Baumer, George Goldsmith, Alonzo C. Devlin.
George Griesel, Joseph Leinmiller,

In the Junior Mechanical Class,

William Meinel, Joseph Ulrich Boss, James Flynn.
Thomas Moore, Gustav Heinecke,

In the Architectural Class,

Stacy Dear, William Burke, Charles Nelson Rocholl,
Howard G. Tomlinson, Richard D. Tifft, Ara S. Pennewell.
Joseph C. Swartz, Stanley K. Weber,

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND, ENTITLING THEM TO TICKETS FOR THE NEXT TERM.

Walter Dardenne, Stacy Dear, William Meinel.
Ernest Baumer, Howard G. Tomlinson.

THE FOLLOWING STUDENTS HAVING ATTENDED A FULL COURSE OF FOUR TERMS, WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES.

Robert J. Heisserman, Olei Johnson,
William H. Weldon, Charles A. Frey,
Walter T. Sulger, James Campbell,
James B. Stites, Edward Allen,
Ephraim Foster, Elmer E. Snyder,
Clarence A. Fish, Charles Herbert Ireland,
Charles R. Yerger, Michael Herbert,
Frank H. Sauer, William Burke,
John Joseph McCormick, Stacy Dear,
John A. Schneider, Richard D. Tifft,
David H. Trego, Joseph F. Harris,
Edward Frehafer.

THE SCHOOL OF MACHINE DESIGN.—During the past session the policy adopted at the time of the school's organization has been continued of covering a relatively narrow field in construction engineering and requiring that this be carried on in a thorough manner.

This policy does not encourage any but those who are sincere in their desire to master the subjects offered and willing to devote the greater part of their leisure to that effort.

There is a mistaken impression among many who are about to undertake study of this kind that satisfactory results may be expected by devoting to it only the time scheduled for class hours and in consequence the preparatory classes suffer considerable losses by the resignation of men who cannot, through lack of application, keep pace with the prescribed development of the subject. In addition to covering, in detail, the ground specified a constant effort is made to lead the student to the habit of independent thought, and to that end he is encouraged never to accept the conclusions of a text without satisfactory proof. Indeed, at no stage of the course is the student offered a result without demonstration. The aim has been briefly, to make the course a deductive one and to eliminate features that savor of "cook-book" system of engineering instruction.

As may be expected there are no text-books fully adapted to meet the needs of such a course due to the limited field of the mathematics employed. To meet this deficiency the instruction staff has prepared hektograph notes, supplementing the texts adopted, for distribution in the classes. There is now a considerable accumulation of these notes and if the opportunity is found they will be incorporated in future text-books compiled to meet the particular needs of the course.

The poor furnishings of the school are, of course, unattractive and have often been commented upon, but it may be pointed out that the efficiency

of a school is not measured by elaborate equipment, but by diligence and capacity of the student body and teaching staff.

The Director welcomes this opportunity of acknowledging his indebtedness for their painstaking and efficient co-operation to Mr. C. F. Chambers, who conducts the class in algebra, and Mr. Arthur C. Heintze, who directs the class in geometry and trigonometry. LUCIEN E. PICOLET, *Director.*

THE FOLLOWING HAVING SATISFACTORILY COMPLETED THE REQUIREMENTS OF THE COURSE ARE ACCORDINGLY AWARDED CERTIFICATES:

A. J. Beuter, C. F. Krauss, A. H. Petri.
E. C. Gardiner, W. L. Lukens,

THE SCHOOL OF NAVAL ARCHITECTURE.—The small attendance at the Night School of Naval Architecture is very largely attributable to the fact that the average draftsman employed in the shipbuilding yards of this country does not realize the importance, or even the desirability of becoming acquainted with the scientific features of shipbuilding. The idea is prevalent that theory is in most cases diametrically opposed to practice, and that therefore a practical experience is far more valuable than a theoretical education. The fact is lost sight of that theory is never at variance with practice, but on the contrary, that theory is entirely the result of practical experience carefully observed and analyzed. The pernicious result of this idea is that the majority of ships draftsmen never become possessed of more than mediocre ability and never become competent to fill positions requiring more than a moderate amount of technical skill. If the great benefit of a scientific training, not only in its direct and immediate application but also because it develops the ability to properly devise economical and efficient solutions of ordinary practical problems, could only be properly appreciated, the number of students would undoubtedly be greatly increased. Other circumstances also operate against a large attendance, such as inadequate facilities for efficient teaching, which is in all probability only temporary, expensive text books, and the short time allotted to the work. These unfavorable circumstances are of a serious character, but they could be in a measure overcome, if a sufficient interest could be aroused among the men from whom the recruits for this course must be largely drawn.

The same difficulties in regard to the inadequate preliminary preparations under which a great many of the students have labored, have been experienced this year as in the past. The utter impossibility of undertaking this course without at least an elementary mathematical training has been responsible for the decreased attendance during the second term. But on the other hand, the earnest endeavor and faithful attendance of those students able to continue has been of material benefit to them and has greatly encouraged the efforts of the instructor. On account of the limited time at our disposal and also because the greatest need seemed to lie in that direction, the attention of the class has been mainly directed toward theoretical naval architecture. M. H. KEIL, *Director.*

The following students have successfully completed the required course of two years and are therefore entitled to certificates of graduation: Joseph McDermott, Wm. Serad, Jr., Chas. Vanstone.

FRANKLIN INSTITUTE

(Proceedings of the stated meeting held Wednesday, April 21, 1909.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1909.

President WALTON CLARK in the Chair.

Present, forty members and visitors.

Additions to membership since last report, four.

A communication was presented from Mr. Henry Howson, surviving trustee of the Elliott Cresson Medal Fund, announcing the death of his co-trustee, Dr. William H. Wahl, and requesting that another trustee be elected to fill the vacancy. In accordance with the deed of trust the matter will lie over until the next meeting.

The Chairman announced the death of Dr. Persifor Frazer and called attention to the vacancy on the Board of Managers. On motion, duly seconded, Mr. James S. Rogers was nominated to fill the vacancy, and as there were no other nominations he was unanimously elected.

The paper of the evening was then presented by Mr. Charles E. Rice, M.E., on the "Evolution in Design, Manufacture, and Uses of Typewriting Machines." The speaker reviewed the history of the typewriting machine, beginning with the invention of Thomas Hall in 1880 up to the present time, giving special attention to the construction and manufacture of the Underwood Typewriter.

Mr. Charles V. Oden then gave a demonstration of the practicability of the Underwood Typewriter; he was assisted by Miss Rose L. Fritz who recorded the speaker's introductory remarks, 570 words in five minutes and twenty-four seconds. Miss Florence E. Wilson demonstrated the speed of the Underwood Typewriter by copying one hundred and sixteen words of reading matter in one minute. Mr. H. O. Blaisdell recorded two hundred and twenty words of unfamiliar matter from a newspaper in two minutes. Mr. E. Trefzger took dictation at the rate of 227 words in two minutes.

On motion a vote of thanks was tendered the speakers and the demonstrators for their interesting papers and exhibition. Mr. Rice's paper was referred for publication, and the subject of the Underwood Typewriter was referred to the Committee on Science and the Arts for examination and report.

JAMES CHRISTIE,
Secretary.

COMMITTE ON SCIENCE AND THE ARTS

(Abstract of proceedings of the stated meeting held Wednesday, April 7, 1909.)

MR. J. Y. MCCONNELL in the chair.

The following report was adopted:

(No. 2446.) *Milling Files.*—Alexis Vernaz, Yverdon, Switzerland. Reserved for publication in full. The Elliott Cresson Medal is awarded to the inventor. [Subcommittee.—William H. Thorne, Lucien E. Picolet, George S. Cullen.]

The following protest was disposed of:

(No. 2400.) *Primary Battery.*—Frank A. Decker, Philadelphia.

(An advisory report.)

The following report passed first reading:

(No. 2449.) *Emergency Exit Door Lock.*—Hugh Elmer Clark, Rochester, N. Y.

R.

BOOK NOTICES

ALTERNATING CURRENT MACHINES. Being the second volume of "Dynamo Electric Machinery, its Construction, Design, and Operation." By Samuel Sheldon, A.M., Ph.D., D.Sc., Professor of Physics and Electrical Engineering at the Polytechnic Institute of Brooklyn and Past-President of the American Institute of Electrical Engineers; and Hobart Mason, B.S., E.E., Associate of the American Institute of Electrical Engineers; and Erich Haasmann, B.S., E.E., Instructor in Electrical Engineering at the Polytechnic Institute, Brooklyn, and Associate of the American Institute of Electrical Engineers. Seventh edition; completely rewritten; xi + 353 pages, 5¼ x 7½ inches. D. Van Nostrand, New York; Crosby, Lockwood, London. Price, $2.50 net.

The appearance of the seventh edition of this book bears testimony to its value in the field covered. The subject has been treated rather with view to meeting the needs of students who are endeavoring to master the subject by their own efforts than of engineers who presumably already know the subject and whose requirements are met by a less detailed account.

The mathematics employed cover the range of subjects usually presented in an undergraduate engineering course and the book's greatest field of usefulness undoubtedly lies in its inclusion in such a course rather than among students of the self-instruction class.

The value of numerical computation has been duly borne in mind by the inclusion of a large number of examples at the end of each chapter.

L. E. P.

POLARISATION ET SACCHARIMETRIE. Par D. Sidersky, Ingenieur-chimiste. 168 pages 4½ x 7½ inches; with 40 illustrations. (Encyclopedie scientifique des Aide-Memoire.) Price, paper, 2 francs 50; cloth, 3 francs. Gauthier-Villars, Paris, 1908.

The study of rotary polarization and its numerous practical applications to analytical chemistry is thoroughly set forth in this small volume and the various forms of instruments used are illustrated and described in detail.

The new edition is brought up to date by the inclusion of the latest researches on the subject, and the volume should prove of the greatest value to the analyst utilizing this method.

L. E. P.

LABORATORY EXPERIMENTS IN METALLURGY. By Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University, and H. M. Boylston, Instructor in Mining and Metallurgy in Harvard University. Seventy-three pages, illustrations, plates, tables, 8vo. Cambridge, Mass., The Authors, 1908. Cloth. Price, $1.25.

This book gives an outline of a course in metallurgy which will be useful to those in charge of college work upon this subject. A general idea is given of the properties of some of the more common metals. Several pyrometers are described and one calorimeter. It is rather curious, however, that no mention is made of the bomb calorimeter, which is everywhere recognized as the standard of accuracy.

One-half of the experiments relate to the metallurgy of iron and steel, and most of them deal with the important subject of "heat treatment."

R. J.